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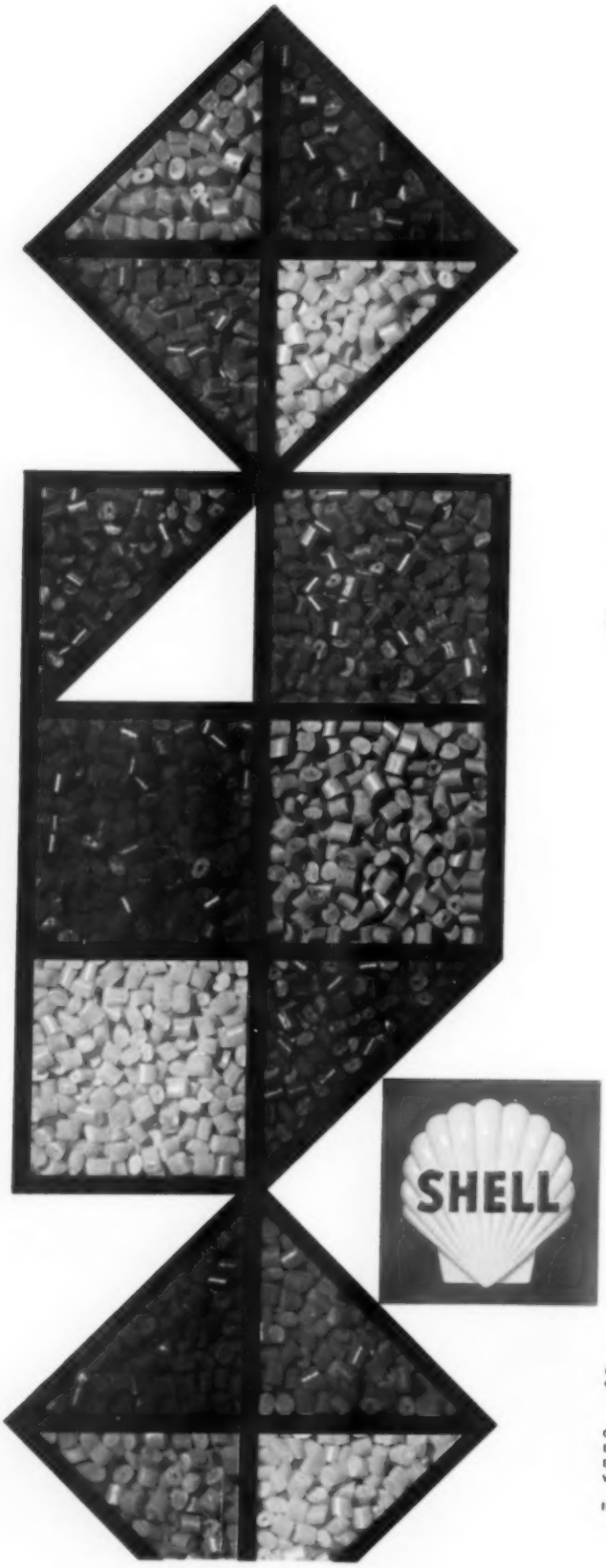

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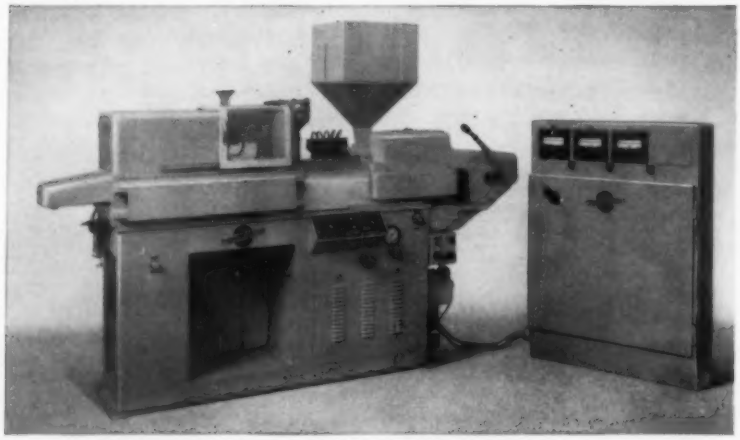

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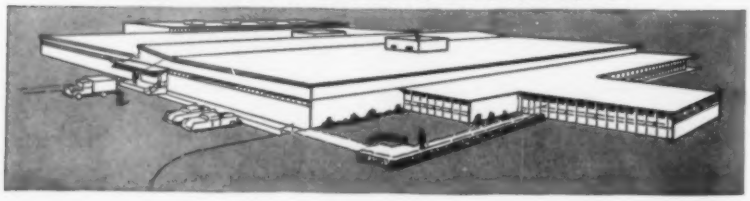

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An international scientific and educational organization of more than 8,000 individual members devoted to the development and dissemination of technical information in the fields of research, design, development, production and utilization of plastics materials and products. The Society is incorporated under the laws of the State of Michigan.

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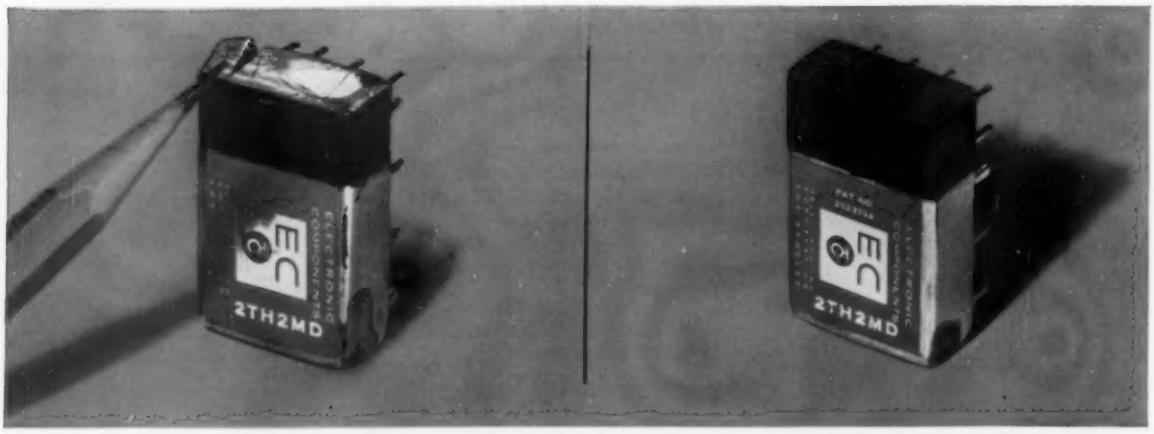
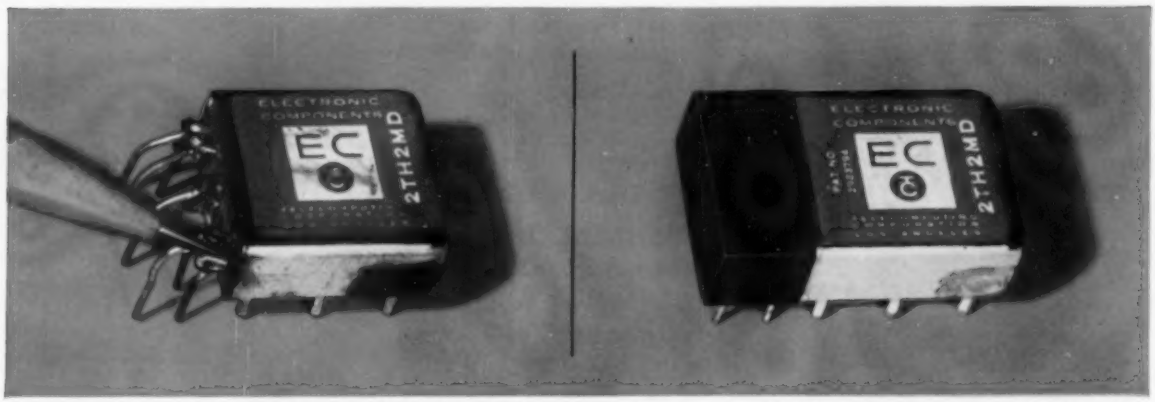
The Cover

Theme of this month's Cover is the SPE Roster of Membership. Beginning on page 821, pages of the Roster are numbered 1 through 116, for convenience of use.

DOW | THERMOSETTING RESINS



Under 180°C. heat, the ordinary epoxy resin cracked . . . but the epoxy novolac potting was unharmed!



In an epoxy stripper, the epoxy resin potting dissolved . . . but the epoxy novolac showed no significant change after two weeks' immersion!

DOW EPOXY NOVOLAC UNHARMED

by brutal heat and chemical torture tests!

Tests conducted by an electronics component manufacturer prove it! Compared on the basis of their ability to withstand extreme heat and powerful chemical attack, these two micro-miniature relays demonstrated the amazing difference between a regular high-quality epoxy resin, and Dow epoxy novolac resin (D.E.N. 438).

The test to determine the effects of prolonged intense heat on these two terminal pottings took place in a 180°C. oven. After five hours, the ordinary epoxy resin potting compound cracked. But after 100 hours of continuous 180°C. heat, the Dow epoxy novolac was unharmed!

A chemical resistance test compared the ability of each potting compound to withstand the action of high-powered stripping solvents similar to solvents used in cleaning electronics equipment. The ordinary epoxy resin formulation was completely dissolved after only 48 hours in the stripper. But the Dow epoxy novolac potting showed no significant change, even after two weeks' immersion!

These results prove once again that in potting, molding, encapsulating and laminating, or in any application where performance is critical, Dow epoxy novolac resins can provide the extra measure of physical and chemical stability necessary for success.

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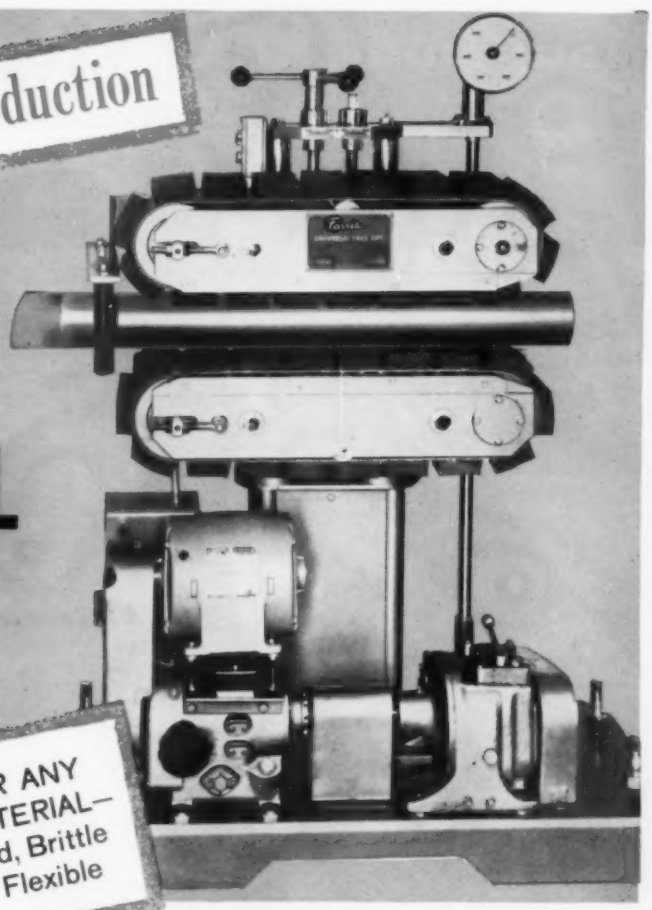

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EDITORIAL

SPE's Roster of Membership

Featured in this month's SPE Journal is the Society's Roster of Members. It is the most complete, detailed, accurate SPE Roster ever published. It was made possible through the combined efforts of SPE Headquarters staff personnel and the cooperation of members in returning the Roster questionnaire. Over 75% of the Society's members responded. Unlike past Rosters, the one published in this issue shows members' company affiliations **and** job titles. A quick look can show who works for which company, and what he is doing. In addition, the Roster also lists members alphabetically by Section.

While this year's Roster does not show how many foreign members the Society has, the list is indeed international, as our cover design for this month implies. A look into the country affiliations of non-section members (of which about 95% are from countries other than the U.S.,) reflects the fact that SPE is truly an international Society. There are, for example, 32 nations represented by SPE membership. Largest non-U.S. membership is in Canada, with 326 members. Japan and Mexico are tied for second place, each with 32 members. Then we have 15 members in Australia, 14 in England, 12 in Switzerland, 11 in Germany. The list goes on to include members in Argentina, Belgium, Cuba, India, Italy, South Africa, and Spain, and others.

We are confident that, as productivity in the nations of the free world grows, so will the international membership in SPE.

Another Plank in the PAG Platform

About the same time as you receive this issue of the SPE Journal you will also receive in the mail a copy of our new PAG brochure and a brief questionnaire concerning your technical area of greatest professional competence and/or interest. The results of this questionnaire, which will give us a picture of the technical interests of our membership, represent another plank in the PAG platform.

But, once again, the plank can't be put into place unless each member does his part. We earnestly request that each of you complete and mail the simple post card questionnaire so that it will arrive at the Executive Office by September 6. In this manner you can contribute to PAG activities and help to make this a banner year for Professional Activity.

Frank W. Reynolds,
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WRITE FOR TECHNICAL BULLETIN 1-19G

This 32-page bulletin gives details on these and other applications of NADONE, contains complete properties, reactions and a valuable list of 148 literature references. We'll gladly send you a copy of this bulletin and, if you wish, a liberal working sample of NADONE for your investigations.

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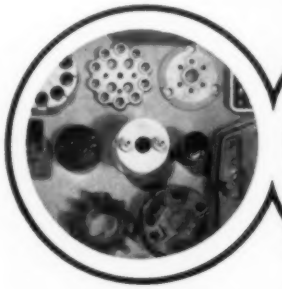

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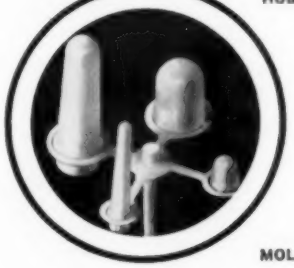

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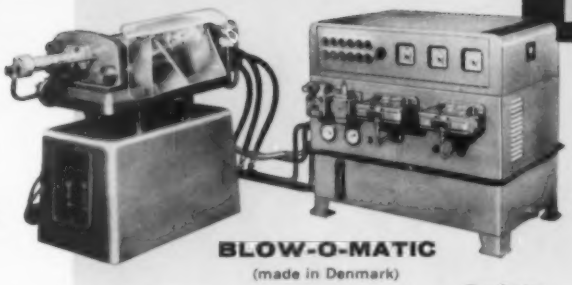

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	2 gal.	600
All Hydraulic	5 gal.	125

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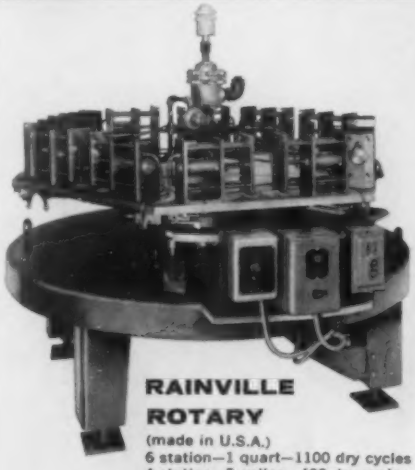
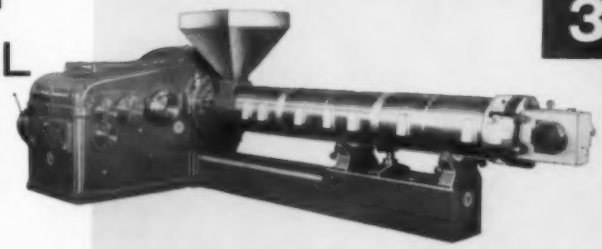


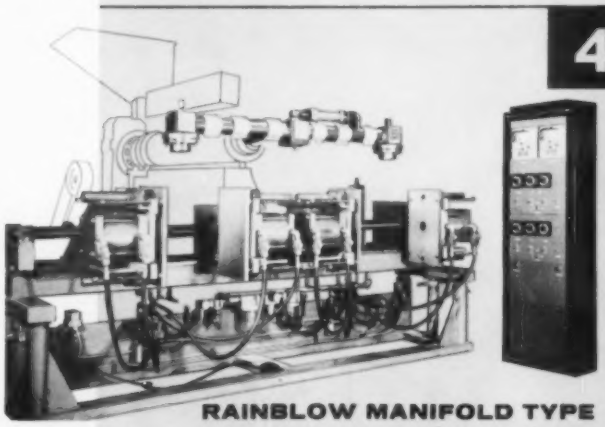
RAINVILLE ROTARY
(made in U.S.A.)
6 station—1 quart—1100 dry cycles
4 station—5 gallon—400 dry cycles
6 station—1 quart—2400 dry cycles
(1, 2 or 3 bottles per station)
MECHANICALLY AIR OPERATED

3



The new RAINVILLE EXTRUDERS
A complete line of imported extruders from 1" to 8"
PLUS—a new line of Domestic Extruders—

4



RAINBLOW MANIFOLD TYPE BLOW MOLDING MACHINES

Platen Dimensions:	12x20
Maximum Thickness of Part:	11 inches

5

RAINKOOL
Refrigerating and Recirculating Units.

Portable, from 3 HP to 20 HP

Air or water cooled

Rainkool Units are trouble free and are guaranteed for one year. These are the first units available RATED IN LBS./HR. OF PLASTIC PROCESSING CAPACITY. Units are running successfully on injection molding, blow molding and extrusion bath applications.

PLUS "NEW" RAINTOWER COOLING TOWERS

6

AUTOTHERM

Mold Temperature Control Units

- All brass and copper piping
- Single setting for heating and cooling
- Single—Double—Triple
- high temperature oil units
- low-price atmospheric temperature units
- cooling only units.

A Molding Foreman's Dream Unit

Do You Need

A PLASTICS DIVISION?

A PRODUCTION MACHINE?

ACCESSORY MACHINES?

OR

YOUR PLANT MODERNIZED?

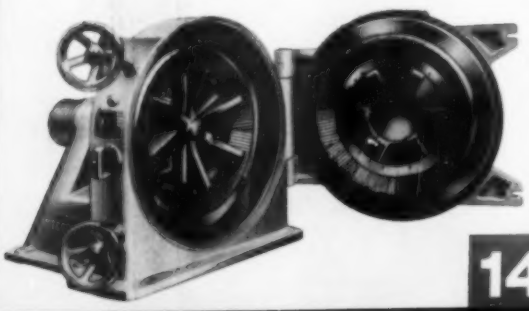
A PRODUCT ANALYZED?

The Rainville Company, Inc.

839 Stewart Ave., Garden City, L. I., New York

PALLMANN MILLS

for "Powdered" Thermoplastics down to 100 mesh without refrigerant.



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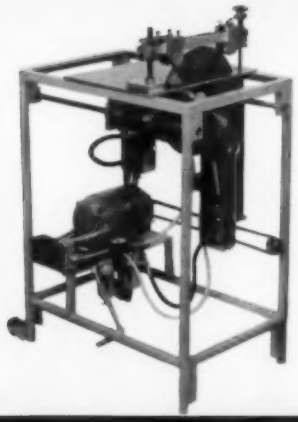
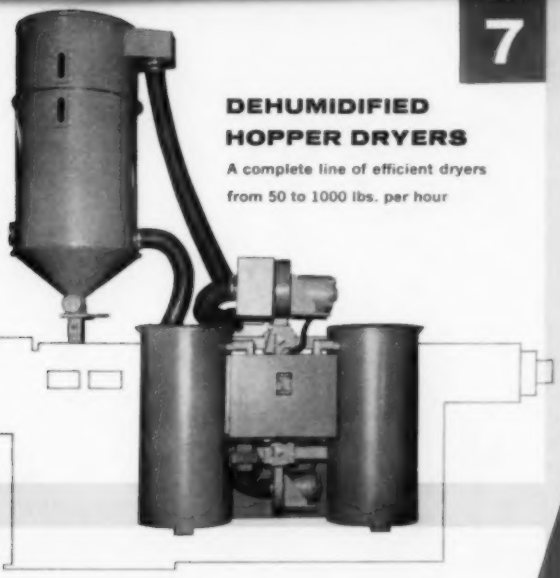


VERN EMERY CUT-OFF SAWS

SHOWN WITHOUT COVER

Efficient travelling cut-off saws—14" and 24"

13



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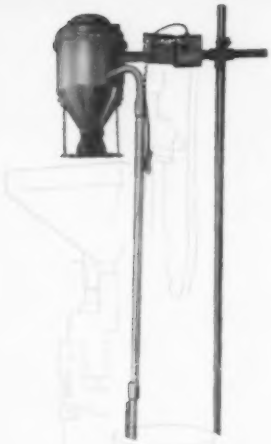
DEHUMIDIFIED HOPPER DRYERS

A complete line of efficient dryers from 50 to 1000 lbs. per hour



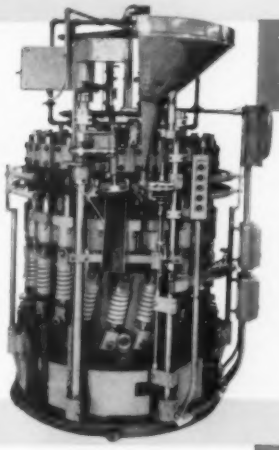
8

RAINCO AUTOMATIC VACUUM HOPPER LOADERS

DUST FREE!!

LR-1000 Series—1200 lbs./hr.
LR-2000 Series—1800 lbs./hr.

Proportional Loading also available.



9

ROTARY COMPRESSION MOLDING

3½ to 10 tons per station—20 station. Fully automatic **continuous** compression molding with powder or preforms.

Manufactured by

Warren Components Division of El-Tronics, Inc.

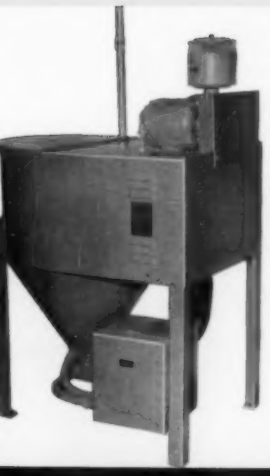
Warren, Pennsylvania

10

ROTARY TRANSFER MOLDING

Ten station continuous rotary transfer molding for such material as polyester pre-mix, epoxies, alkyds and rubber.

Also operable for insert molding.



DRYER LOADERS

For low ceiling plants—
These units may also be dehumidified

12

RAINCO DRUM TUMBLERS

ORIGINAL FLOOR LEVEL LOADING.

	Max. Drum Size
T-100 Series	23" dia. x 32" high
T-200 Series	23" dia. x 44" high

Drum Extenders also available

Power saved by balanced drum holder design.

11

The Second Stage Injector was designed to increase the effective operation of any Impco Injection Molding Machine now in service. It is also now available as standard equipment on new Impco machines. Its use gives you:

- Raw material savings
- Increased capacity
- Reduced molding pressures
- Increased mold area
- Simplified nylon molding
- Fewer rejects

Ask for Bulletin P-127 for more information.

IMPCO®

IMPROVED
MACHINERY INC.
NASHUA, NEW HAMPSHIRE

MANUFACTURERS OF IMPCO PLASTIC MOLDING MACHINES

COMPARE ... ADMEX 770 against other polymeric plasticizers—in these 4 significant tests!

RUBBER MIGRATION

	Admex 770	Polymeric X	Polymeric Y
Neoprene	0.6	2.67	1.06
GRS	0.23	2.01	1.22

VINYL-RUBBER CONTACT frequently solves many industry problems. Admex 770 shows the highest resistance to migration into rubber products used for electrical cables, floor mats, shoe liners and rubber-based adhesives.

SOAP EXTRACTION

	Admex 77	Polymeric X	Polymeric Y
200F (24 hrs.)	3.48	4.99	3.41
140F (24 hrs.)	1.64	3.65	3.03
Cycling 140F (3 hrs.)	1.27	2.79	2.11

ADMEX 770 insures long-term flexibility in vinyl products subjected to soapy water contact, either by static or cycling exposure. Try Admex 770 in floor and wall covering, in supported and unsupported sheet, in many organosol and plastisol applications.

STYRENE CRAZE

Comparative Retention of Tensile Strength — Admex 770 | Polymeric X | Polymeric Y

Stress cracking of molded polystyrene

REFRIGERATOR GASKETS compounded with Admex 770 show improved resistance to crazing and marring of polystyrene. Excellent blending and extrudability, plus low odor level, make this polymeric an ideal choice for high quality profiles.

SOLVENT RESISTANCE

	Admex 770	Polymeric X	Polymeric Y
Gasoline	0.39	0.62	0.56

DO YOUR upholstery, film and sheet specifications call for high solvent resistance? Admex 770 proves superior to many costlier polymerics in its resistance to extraction by fuel and cleaning type solvents.

For data and samples, write today:

Admex
Vinyl Plasticizers

Archer-Daniels-Midland

Archer QUALITY

717 INVESTORS BUILDING, MINNEAPOLIS 2, MINNESOTA

ADM PRODUCTS: Linseed, Soybean and Marine Oils, Synthetic and Natural Resins, Fatty Acids and Alcohols, Vinyl Plasticizers, Hydrogenated Glycerides, Sperm Oil, Foundry Binders, Bentonite, Industrial Cereal, Vegetable Proteins, Wheat Flour, Dehydrated Alfalfa, Livestock and Poultry Feeds.

SPE JOURNAL NEWSLETTER

reading time
1 minute

Advances in Epoxies

A new process makes possible production of a variety of new epoxy resins. Developed by Union Carbide Chemicals Corp., the process uses peracetic acid to form epoxides with a wide group of structures including dicyclic compounds. Diepoxides thus formed have good heat resistance and give hard surface coatings. Of particular significance: Acid-type hardeners can be used as curing agents instead of the more expensive and more toxic amine hardeners. Also on the horizon, and soon—one shot epoxy resin systems that can be cured by heat alone.

Ceiling Temperature for Polymers

A useful concept of importance to polymer stability and mechanisms of decomposition is ceiling temperature. The article on page (810) discusses this concept and gives ceiling and decomposition temperatures for a number of polymers, including polyethylene, polystyrene, and polypropylene.

A New Quality Control Tool?

Molten viscosities of vinyl chloride polymers can be used as a basis for classifying by fabricators, according to end use. Data developed (and soon to be published in the SPE Journal) so far indicate that such a system could be of considerable value as supplementary information for vinyl (chloride and acetate) processors. Big advantage over using usual solvent relative viscosity is that ease of processing is conveniently determined without the complications of variable solvents, concentration effects, or changing polymer types.

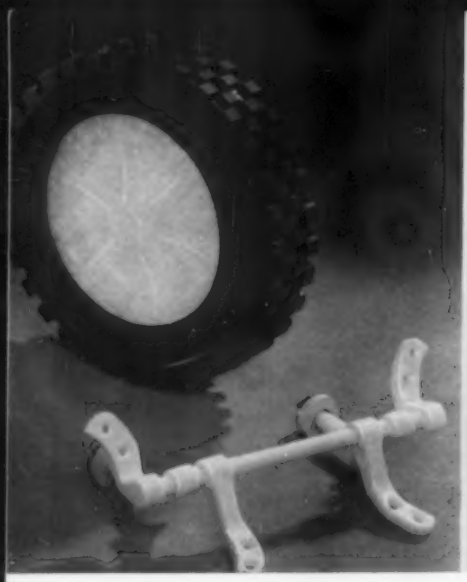
Furane Pipe

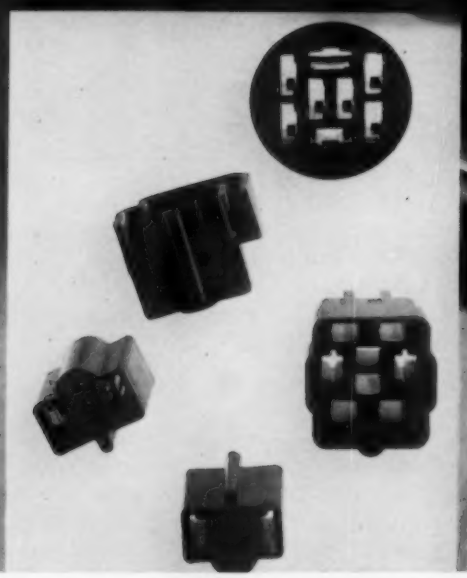
Reinforced plastic pipe that can carry hot corrosive liquids and gases at temperatures up to 300°F. and at pressures up to 150 p.s.i.g. has recently been developed. Resin used in making the pipe is a furane resin while the reinforcing material is a woven borosilicate glass fabric. Pipe can be cut to length with a hacksaw or brick saw.

Plastic-Copper Laminates

Polyethylene and other polyolefins can be bonded to high copper alloys if there is a thick enough cupric oxide film on the metal surface of the alloy. The metal surface can be oxidized by chemical or thermal means and bonding of the plastic is done under pressure, starting at about 200°C. and subsequently cooling to 125°C, then to room temperature. Reports indicate that the strength and reproducibility of bonds formed by this method are strong enough for use in structural applications.

new technical ideas • trends • industry news





Meet AviSun Polypropylene. The structure and molecular weight of this new thermoplastic can be tailored to make a variety of end products, including: hospital and laboratory ware; appliances; automotive and aircraft parts; housewares; toys; containers; closures; electrical items; fibers; rope and packaging film.

LIGHTEST of all plastics. Up to 50% more molded parts per pound.

HIGHLY HEAT RESISTANT . . . with a melting point of 330° to 340°.

MOST RIGID of the polyolefins, plus high surface gloss and abrasion resistance.

EASY PROCESSING by various means: injection molding, blow molding, extrusion, vacuum forming and film and sheet extrusion.

*

AVISUN

CHARACTERISTICS

CHEMICAL performance is excellent. End products are highly resistant to detergents and other stress cracking agents. The material resists most acids, including hydrochloric and sulphuric, as well as alkalies even at elevated temperatures. Resists gasoline, motor oils, foods, and plating, pickling and salt solutions. At high temperatures Polypropylene will swell in solvents such as toluene, carbon tetrachloride and also oxidizing acids. AviSun certifies that its polypropylene meets the conditions of F.D.A. regulation on the use of polypropylene for food packaging.

MECHANICAL—The stiffness modulus of polypropylene is greatest of all polyolefins, and puts polypropylene in the classification of "rigid" plastic materials. Retains strength and stiffness at elevated temperatures better than any competitive thermoplastic. Has high compressive strength and resistance to deformation at high temperatures. Toughness exceeds that of polystyrene at low temperatures. The tensile strength of Polypropylene is the highest of all the polyolefins. At normal test rates, molding grades will show elongations up to 500%.

ELECTRICAL—Being a nonpolar material it exhibits very low losses in alternating electrical fields. Its high heat distortion and softening temperature are ideal for many electrical uses. High volume resistivity and ease of extrusion make wire and cable insulation an important potential application. Its low dissipation factor makes it attractive for high frequency insulation. Low moisture absorption makes Polypropylene components electrically stable. Good mechanical and processing properties make the electrical characteristics even more desirable.

PHYSICAL — AviSun Polypropylene has a linear, ordered structure which can be highly crystalline. This "tailored" structure is reflected in its many unique properties. In addition, its chemical, mechanical and electrical behavior are generally improved over the known performance of other "isotactic" polyolefin structures. As the material becomes more highly crystalline, the tensile strength and modulus increase, but other qualities change somewhat as well. Therefore, AviSun Polypropylene has been formulated to an optimum balance of end properties.

TECHNICAL ASSISTANCE—AviSun Technical Specialists are at your service. They will answer your specific questions about AviSun Polypropylene . . . and help you plan better products at lower cost with this versatile new thermoplastic.

PHONE HUbbard 5-5831 or write

AVISUN CORPORATION

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Polypropylene

the new thermoplastic . . . exciting new product opportunities!

PROPERTIES OF INJECTION MOLDING AND EXTRUSION GRADES

TABLE 1 — Typical Physical Property Values

Property	A.S.T.M. Test Method	Units	Values: Extrusion Grade	Values: Injection Molding Grade
Tensile Yield Strength	D-638-58T (0.2 in./min.)	psi	4700	4900
Total Elongation	D-638-58T	%	300	400
Stiffness (flexural)	D-747-50	10^5 psi	1.8	1.8
Izod Impact	D-256-56	ft. lb./inch of notch	1.3	0.8
Hardness				
Shore	D-676-55T	D	74	74
Rockwell	D-785-51	R	75	80
Deformation under load—2000 psi, 122°F, 24 hrs.	D-621-51	%	3.2	3.2

TABLE 2 — Typical Physical Property Values for Both Grades

Property	A.S.T.M. Test Method	Units	Values
Form	—	—	⅛" Pellets
Bulk Factor	D-1182-54	—	1.8
Specific Gravity	D-792-50 Method A	—	0.910-0.920
Refractive Index	—	n_D^{25}	1.510
Water Absorption	D-570-54T (24 hr. at 73°F)	%	nil
Heat Distortion	D-648-56	°F	
66 psi	—		240
264 psi	—		150
Flammability	D-635-56T		slow
Coefficient of Linear Thermal Expansion	D-696-44	10^{-5} in./°F	
		46 to 154°F	6.7
		97 to 205°F	8.9
Specific Heat	—	cal./°C/gram	0.45
Mold Shrinkage	—	in./in.	0.010-0.025
Environmental Stress Cracking	Bell Laboratory Method 100% Igepal	Years	>2

TABLE 3 — Typical Electrical Property Values for Both Grades

Property	A.S.T.M. Method	Units	Values
Power Factor	D-150-54T		
at 10^2 cycles			<0.0007
at 10^3 cycles			0.0002
at 10^6 cycles			0.0002
Dielectric Constant	D-150-54T		
at 10^2 cycles			2.3
at 10^3 cycles			2.3
at 10^6 cycles			2.1
Dielectric Strength	D-149-55T (.032 in. thickness)		
Short Term @ 73°F		volts/mil	1040
Step by Step @ 73°F		volts/mil	950
Volume Resistivity	D-257-57T	ohm-cm	$>3\times10^{15}$
Surface Resistivity	D-257-49T	ohms	$>3.4\times10^{14}$

TABLE 4 — Typical Chemical Properties for Both Grades

Chemical	% Weight Change After 30 Days Immersion @ 73°F
Distilled Water	+0.015
Inorganic Acids	
Sulfuric Acid 30%	+0.01
Nitric Acid 10%	+0.013
Hydrochloric Acid 10%	+0.013
Organic Acids	
Acetic Acid 5%	+0.022
Oleic Acid 93%	+0.04
Citric Acid 10%	+0.02
Alkalies	
Sodium Hydroxide 10%	+0.002
Sodium Hydroxide 1%	+0.009
Ammonium Hydroxide 10%	+0.03
Sodium Carbonate 2%	+0.024
Organic Solvents	
Ethyl Alcohol 95%	+0.048
Ethyl Alcohol 50%	+0.027
Acetone	+0.68
Ethyl Acetate	+2.84
Ethylene Dichloride	+7.84
Carbon Tetrachloride	+30.0
Toluene	+10.54
Heptane (boiling point)	+11.01
Phenol	+0.041
Other	
NaCl Solution 10%	+0.02
Hydrogen Peroxide 3%	+0.03

INTRODUCING THE EGAN AIR COOLED EXTRUDER

Here is the air cooled extruder that offers more effective cooling than any other comparable model on the market today!

Each cylinder zone on the new Egan Air Cooled Extruder is fitted with a high capacity blower. Air from each blower is channeled through the ductwork and a specially designed chamber for a completely dependable, high-velocity flow along the periphery of the zone. You get maximum uniform cooling!

In addition, the Egan Air Cooled Extruder retains all the time tested and proven features found in Egan's other extruder lines—heavy duty thrust bearings, herringbone gear speed reducers, and a host of other operating and maintenance features.

Whatever your requirement in extruders—air cooled, direct electric heat, or "Willert Temperature Control System"—Egan can meet your every need.

Egan Extruders are available in sizes from 2" through 10" with L/D ratios from 20:1 through 32:1.

FREE—Write for your Egan Extrusion Speed Calculator for film, coating and laminating.

CABLE ADDRESS: EGANCO—SOMERVILLE (N.J.U.)

Egan FRANK W. EGAN & COMPANY
SOMERVILLE, NEW JERSEY

MANUFACTURERS OF PLASTICS EXTRUDERS & ACCESSORIES; PROCESSING MACHINERY FOR PAPER, FILM & FOIL; AIR DRYING SYSTEMS; ROTOGRAVURE PRINTING PRESSES; TEXTILE FINISHING MACHINERY.

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FEELS DRY... top compatibility with FLEXOL PLASTICIZER EPO

No oily film . . . no dirt pick up. These are the big advantages CARBIDE has built into FLEXOL Plasticizer EPO.

This premium-grade, high-molecular-weight, epoxy plasticizer demonstrates its top-level compatibility in vinyls even after hundreds of hours of rigorous testing. FLEXOL EPO gives your vinyl products full sales appeal at purchase, and lasting satisfaction in use.

Only two to seven parts of FLEXOL EPO per 100 of resin are required for stabilizing purposes. For dual use as a stabilizer-plasticizer, concentrations of only 10 to 50 per cent of the total ingredients are needed. Primary plasticizers such as FLEXOL DOP can be used easily with EPO.

FLEXOL EPO and other members of CARBIDE's big family of vinyl plasticizers are readily available in money-saving compartment tank cars and trucks, carloads, truckloads, and drums in LCL shipments.

For prices and full specifications on FLEXOL EPO, call the CARBIDE Technical Representative in your area. Or write: Union Carbide Chemicals Company, Division of Union Carbide Corporation, 270 Park Ave., New York 17, N.Y.

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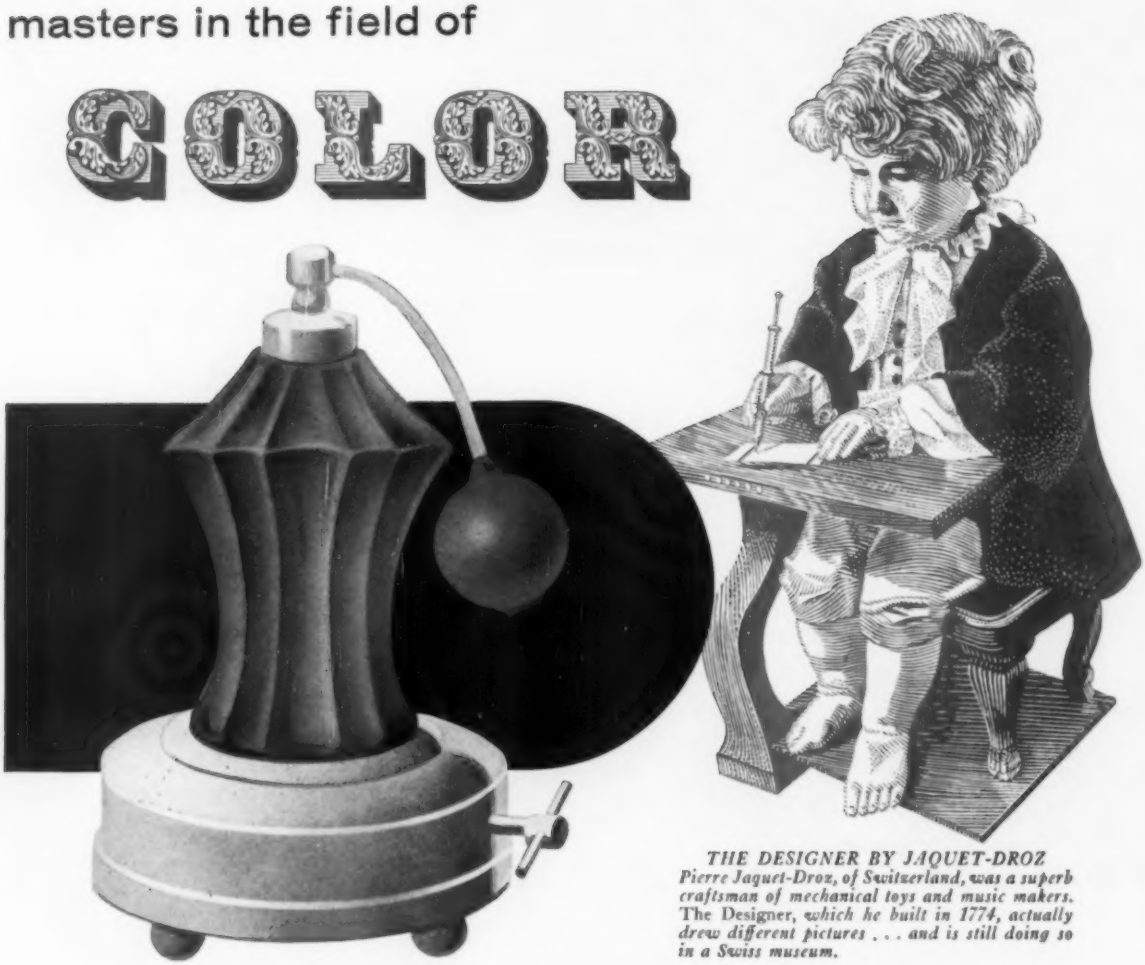
UNION CARBIDE CHEMICALS COMPANY

UNION CARBIDE

masters in the field of

COLOR



THE DESIGNER BY JAQUET-DROZ
Pierre Jaquet-Droz, of Switzerland, was a superb craftsman of mechanical toys and music makers. The Designer, which he built in 1774, actually drew different pictures . . . and is still doing so in a Swiss museum.

Like craftsmen of all eras, modern color formulators combine aesthetic judgment with high technical skills. At Westchester these standards of unusual workmanship have guided the formulation (since we opened shop in 1946) of more than 4000 different color concentrates and pre-mixed color blends. Today, as in the past, Westchester formulates colors with craft and scientific precision . . . colors that do not degrade or migrate . . . colors that exhibit excelent temperature and flow characteristics . . . Westchester Colors!

Write now for detailed information on any color problem involving linear and conventional polyethylenes, polypropylenes, and other thermoplastics.

APPROVED FOR FOOD, DRUG AND COSMETIC PACKAGING

A new series of FDA certified WESTCHESTER colors is now available. These colors are supplied with a registration number, attesting FDA approval of the pigments.

*WESTCHESTER PLASTICS, Inc.

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Custom Compounders of Polyethylene Molding Powder and other Thermoplastic Materials

Manufacturer and Developers of Unicolor and Formacolor *Pliethene, Formacolor, Unicolor® T.M. Reg. U.S. Pat. Off.

used with
AUTO-BLOW MACHINES

Here is an installation of Sterling Extruders working in conjunction with Auto-Blow blow molding equipment. Sterling figures importantly in installations where versatility, coupled with high production and quality is absolutely essential. Sterling Extruders have extensive application throughout the blow molding field, just as shown above—a typical operation using multiple Sterling units on a large production line. Their versatility is demonstrated in this process which requires flexibility, by meeting the demands of varying jobs and conditions. The Sterling Extruder provides superior performance and service, a product of long experience in the plastics industry. Sterlings are available in sizes 1½″ through 8″ with L/D ratios of 21:1, 24:1, or 30:1. Sterling offers a full range of variegated units and installations for both standardized and specialized requirements. For full details, write to—

STERLING EXTRUDERS — *"Designed by plastics men for plastics men"*

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The Society of Plastics Engineers, Inc.

ANNOUNCES PUBLICATION

of a New Scientific Journal . . .

SPE TRANSACTIONS

devoted to plastics science and engineering

Some of the articles already selected for the first issue of SPE Transactions Jan. 15, 1961

- **Studying Polymerization of Thermosets by Electrical Resistivity,** R. W. Warfield and M. C. Petree, U. S. Naval Ordnance Laboratory
- **Mechanism of Ultraviolet Stabilization of Plastics,** J. H. Chaudet, G. C. Newland, H. W. Patton and J. W. Tamblyn, Tennessee Eastman Co.
- **Ultraviolet Degradation of Plastics: Use of UV Absorbers,** R. C. Hirt, N. F. Searle and R. G. Schmitt, American Cyanamid Co.
- **A Study of the Weathering of an Elastomeric Polyurethane,** C. S. Schollenberger and K. Dinbergs, B. F. Goodrich Co.
- **Effects of Molecular Weight Distribution of Flow Properties of Polyethylene,** D. R. Mills, G. E. Moore and D. W. Pugh, U. S. Industrial Chemicals Co.

SPE TRANSACTIONS will be published quarterly with the first issue scheduled for January 15, 1961. Since it will contain articles on basic polymer science and fundamental engineering in the processing and utilization of plastics, it will supplement and complement the SPE Journal.

One of the significant trends in the plastics industry today is the increasing level of its technology. The Society of Plastics Engineers is proud to have set the pace in scientific and engineering advancement. The SPE TRANSACTIONS is its latest contribution to fill a growing need; it will publish articles of the highest caliber, selected by scientists and engineering specialists and judged on the importance of their contributions to the permanent literature.

.... a message to SPE members

from **Frank A. Martin,** *Chairman, SPE TRANSACTIONS Task Force, Publications Committee*

A giant stride was taken in the SPE March of Progress on May 16, 1960, when the SPE Council approved the recommendation of the Publications Committee to establish a fundamental journal to publish papers dealing with the scientific and engineering aspects of plastics materials and their processing. This step was not taken lightly, but rather was the culmination of a two-year study by the Publications Committee, and a Task Force appointed by the Publications Committee whose members included Frank A. Martin, Chairman, Dr. Jesse H. Day, Editor Emeritus, SPE Journal, Eugene C. Quear, 1959 Publications Committee Chairman, and Melvyn A. Kohudic, Editor.

Why "SPE TRANSACTIONS"?

It is both necessary and desirable to provide better publication service primarily for the benefit of our members, and secondly to increase the stature of the Society in the industry. SPE has long been the prime source for generating technical papers which are presented at SPE Conferences and meetings at all levels. With the rapid growth of the Society, we have not been able to publish in the SPE Journal all of the papers which were of long-lasting interest, and worthy of a place in the permanent literature. An expanded publication program was found to be necessary. After consideration of many possible ways to accomplish this expansion, it was decided that the best plan for both the Society, and for you the individual, member was to start a new quarterly journal. SPE Journal will continue to be the news magazine of the Society, and to publish those technical articles of broad general interest.

What will SPE TRANSACTIONS contain?

It will publish only papers in the plastics and polymer field which are selected for their basic scientific and/or engineering value. Papers will be both original and review type. They may be complete or abridged. Reprints of the best articles from other publications, both domestic and foreign, and translations of foreign articles will be published for **your** benefit. SPE TRANSACTIONS will contain no advertising, at least for the first few years.

When will SPE TRANSACTIONS Materialize?

Volume 1, No. 1, will be published in January 1961.

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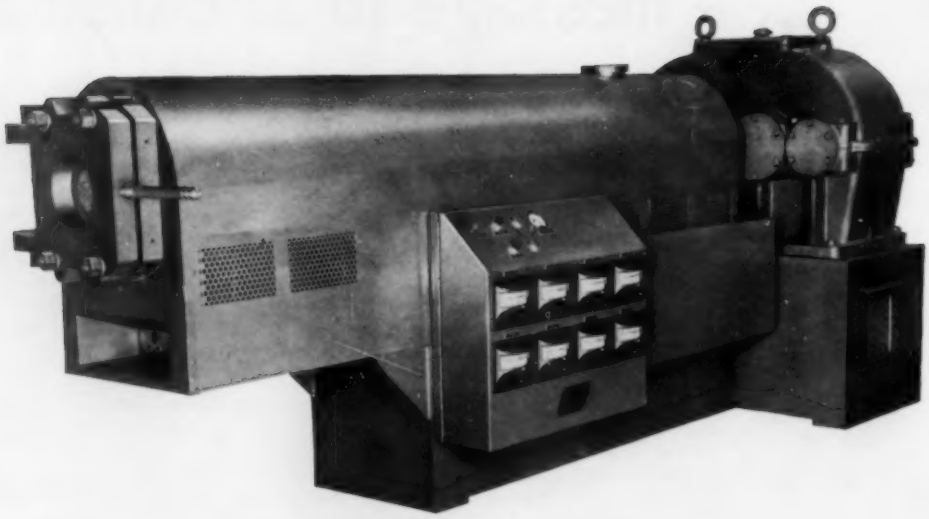

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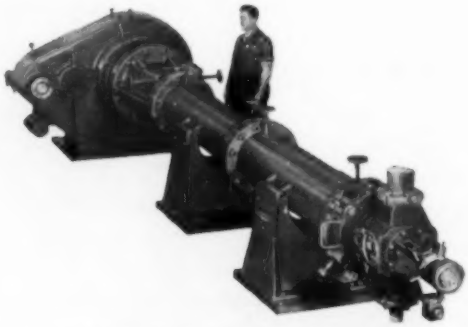

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- **Something new in electrical insulation**
- **A bulletin on plastics**

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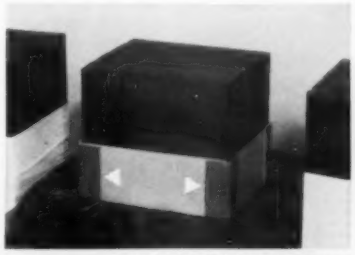

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☐ Hetron fire-retardant polyester resins (data file, including names of fabricators)

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SPECIAL FEATURE

Beryllium-Copper Alloy Molds For Blow-Molding

P. J. Scherbner

Plant Metallurgist, The Beryllium Corp.

The development of suitable plastics has opened a phenomenal future for the blow-molding process. Polyethylene and polyolefin materials are in widespread use in this process today. Research and development efforts are being directed toward the use of cellulosics, vinyls, styrenes and ABS polymers for blow-molding applications.

The development and availability of U. S. design and built blow-molding equipment which is more than able to compete successfully with British and German designs will also give greater impetus to this process.

The economy of the blow-molding process lends itself to the production of many items which are now either being fabricated by other more costly means or too difficult or impossible to produce by any other method. As the recent downward trend in prices of plastic materials continues, designers are turning to the utilization of this process to a greater extent.

In searching for better tooling materials for molds, two beryllium-copper alloys have been found to be among the best materials available. "Berylco" 20C or "Berylco" 275C alloys produced by The Beryllium Corp. exhibit the combination of properties desirable for blow molds and which cannot be found to the same degree in other metals or alloys. High hardness, high strength, excellent thermal conductivity, good corrosion resistance, wear resistance and castability are the properties which lend themselves readily to economical overall production of blow molded products.

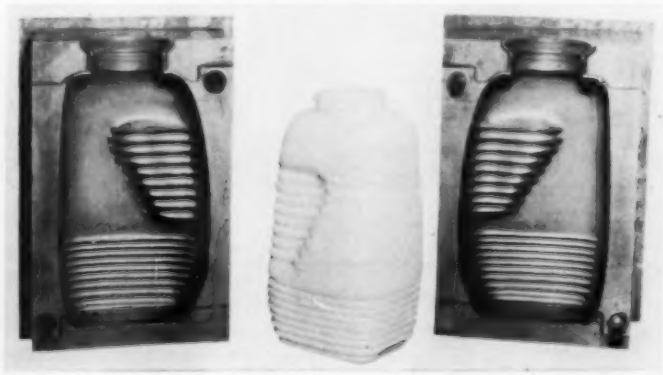


Figure 1. Beryllium-copper blow mold provides sharp pinch-off edge that permits easy removal of excess molding material after molding.

High speed production from blow-molding equipment requires both rapid cooling of the plastic and removal of heat from the molds. This is accomplished by surrounding the mold with a water jacket. The beryllium-copper alloys, due to their good thermal conductivity, aid in removal of this heat to the water. The excellent corrosion resistance of these alloys to water prevents the formation of scale on the water side of the jacket thereby decreasing loss of heat conductivity by the scale layer. Another advantage of these alloys is the ease in which the water cooling coils can be cast as an integral part of the mold. This reduces the possibilities of water leakage and adds to the production efficiency of the process.

A sharp, hard edge is required for the mold in the blow-molding process to pinch the plastic during the process and to prevent flash at the parting line. *Figure 1* indicates how this important equipment is designed into the mold without the need for the addition of hardened inserts. The resulting product illustrates the freedom from flash produced from these dies. Berryllium-copper alloy castings qualify very well for this application, since the castings may be hardened to a Rockwell C reading of 38-42.

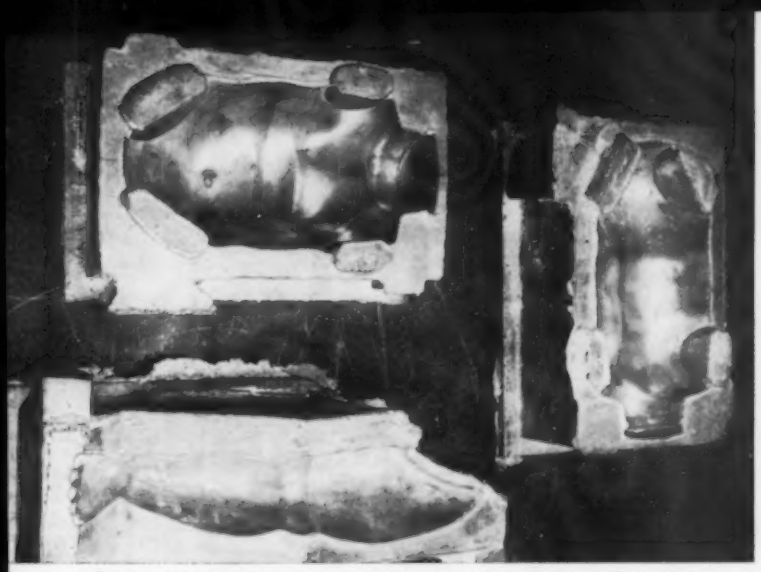


Figure 2. Beryllium-copper blow mold cavities after casting.

Figure 3. Machining of blow mold cavity pinch-off section.

This hardness will be maintained under repeated impacts and all edges of the mold will remain sharp and distinct. As a result the finished plastic product will exhibit a minimum parting line thereby maintaining the quality of the product and reducing the number of rejects on the final product.

Beryllium-copper alloys can be readily melted by one of several means. Electrical, gas, oil or coke furnaces have all been used successfully to melt these alloys. The wide choice of melting equipment does not require the purchase of special equipment and by following proper melting techniques sound, clean castings can be produced. The metal can be poured at comparatively low temperatures, 2000°F or lower.

After the mold designs have been finalized, a choice in molding methods, too, can be employed since beryllium-copper can be poured successfully in sand, plaster, investment or metal molds. This ease of castability is the factor which permits a choice of readily available molding processes.

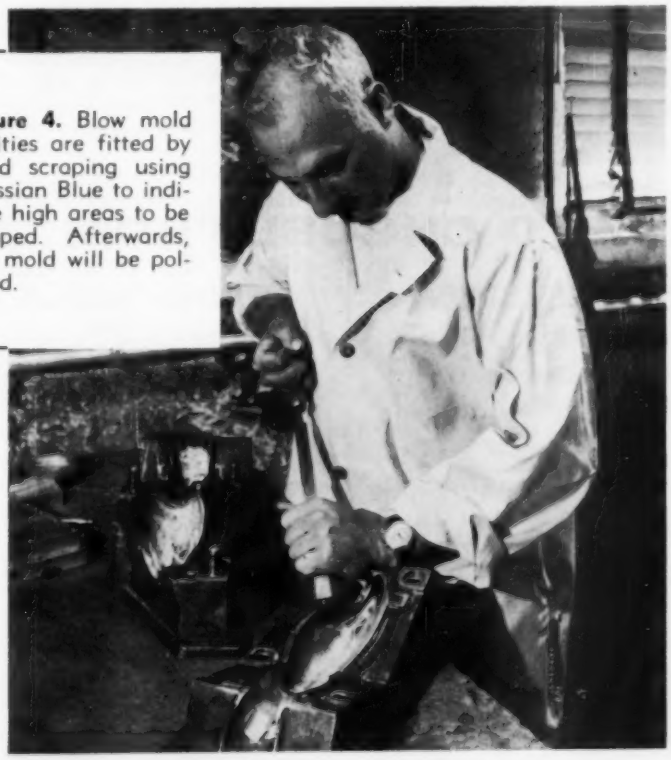


Figure 4. Blow mold cavities are fitted by hand scraping using Prussian Blue to indicate high areas to be scraped. Afterwards, the mold will be polished.

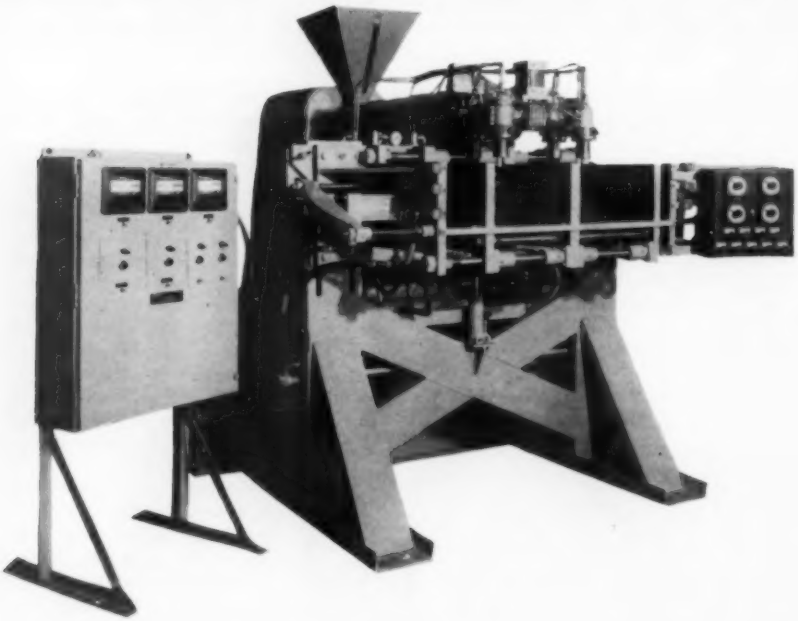
Beryllium-copper alloys are readily freed from the mold medium with excellent surface finish and fine detail. This is due to the fluidity and general cleanliness of these alloys. Because of this, these castings generally require less hand tooling and polishing to produce a finished mold. Castings can be produced with one-quarter (¼") or less wall thickness and lugs or other protuberances which may be necessary for clamping or transporting the mold may be included in the casting. The casting method also provides an economical method for producing a large number of identical molds.

Figures 2 through 4 illustrate the steps used in the production of several blow-molding toy die cavities. *Figure 2* is a photograph of the as-cast mold cavities and *Figures 3 and 4* demonstrate the simple methods by which these cast molds are finished.

Beryllium-copper alloy castings are generally solution annealed after pouring and fettling. In the solution-annealed condition, the castings are soft and easily worked by hand tooling and machining. After polishing and fitting of mold halves, the molds are readily hardened by precipitation hardening at relatively low temperatures. Three hours hardening at 650°F will produce a 38-42 Rockwell C hardness. A final hand polishing after precipitation hardening readies the mold for installation on the blow-molding machine.

Should minor changes in design of mold be required at any time, these design changes may be performed by welding. The metal in beryllium-copper molds may be readily reused in recasting, if major design changes become necessary.

TRICO BLOW MOLDING MACHINES



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Binghamton Section Sponsors Regional Technical Conference on Plastics in Business Machines

The first SPE Regional Technical Conference devoted entirely to "Plastics in Business Machines" will be held on September 22 at the Sheraton Inn in Binghamton, N. Y. Program of the one-day meeting will accentuate the increasing application of a wide variety of plastics materials to virtually every component of modern-day business and office machines. Sponsored by SPE's Binghamton Section, the conference will include papers on the role of plastics in industrial design and finishing operations in addition to those on plastics materials, specifications and component design.

Of particular interest to conference registrants will be the remarks of the luncheon speaker, Dr. Matthew Braidich, Research Director of the National Board of Fire Underwriters. Dr. Braidich will describe the work of a newly organized committee of the Electronics Computer Systems Division of the National Fire Protection Association which is investigating fire safeguards in electronic computer systems. Because of their ever increasing use in such systems, plastics are one of the primary interests of this committee.

General Chairman of the Conference is John E. Gywn of Consolidated Plastics. Requests for advance registrations should be directed to:

John E. Gwyn at Consolidated Plastics
498 Conklin Avenue
Binghamton, New York

Advance registration is	**$ 9.00 for SPE members** **$11.00 for non-members**
"On-site" registration is	**$10.00 for SPE members** **$12.00 for non members**

The complete technical program as announced by Program Co-Chairmen Leroy N. Chellis of IBM Corporation and Joseph F. Murray of Consolidated Molded Products Corporation follows:

Plastics in Business Machines

September 22, 1960–Sheraton Inn
Binghamton, N. Y.

8:00—9:00 a.m. Registration

Morning Session

Moderator: **J. F. Murray,** Consolidated Molded Products Corporation

9:00 a.m.— **Welcome to Binghamton RETEC**
George Puderbaugh, President, Binghamton Section

9:10 a.m.— **Significance of Liquid Epoxy Resins in the Business Machines Industry**
Byron Nelson, E. J. Morrisey and S. D. Marcey
National Cash Register Company

9:40 a.m.— **Design of Spur Gears of Nylon**
Professor Keith Hall
University of Michigan

10:10 a.m.— **Applications of the Polycarbonates in Business Machines**
R. J. Thompson
General Electric Company

10:45 a.m.— **Why Use Epoxy Resin Molding Compounds**
T. E. Battaglini
IBM Corporation

11:15 a.m.— Discussion of Morning Papers

12:15 p.m.— **RETEC Luncheon**
Moderator: Frank W. Reynolds, SPE First Vice-President
Introduction of Society Officers
Remarks—George W. Martin
SPE President

Luncheon Speaker
Dr. Matthew Braidich
Research Director
National Board of Fire Underwriters

Afternoon Session

Moderator: **L. N. Chellis,** IBM Corporation

2:30 p.m.— **Flame Retardant Laminates for Business Machine Applications**
A. J. Green
National Vulcanized Fibre Company

3:00 p.m.— **Writing Meaningful Specifications for Plastics Parts**
Henry S. Byrne
E. I. du Pont de Nemours & Company

3:30 p.m.— **The Industrial Design Approach to Plastics in Business Machines**
Phillip H. Stevens
Stevens-Chase Design Associates
Industrial design consultants for Smith-Corona Company

4:00 p.m.— **Paint as an Engineering Material for Plastics Business Machine Parts**
T. E. Hayden
Bee Chemical Company

4:30 p.m.— Discussion of Afternoon Papers

5:00 p.m.— Adjournment

Should time permit, an alternate paper will also be presented—

Encapsulation of Electronic Components
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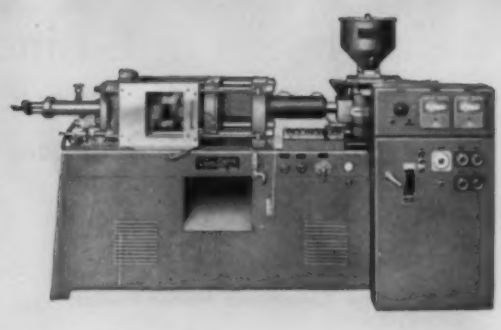

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ACCURATE STRAIN GAGE ANALYSIS OF PLASTICS REQUIRES VISCOELASTIC DATA

Strain gages are becoming increasingly important analytical tools for plastics engineers and designers. However, in using them to evaluate the behavior of plastics under conditions of stress and strain, designers have found that accurate interpretation of strain gage readings is possible only if the readings are related to other factors—notably, time, temperature and environment.

Because standard strain gages (both bonded wire and metal foil types) detect strain by changing electrical conductivity when bent or distorted in any manner, careful mounting on the test part is essential to accurate readings. Once secured to the surface of the test part, however, a gage will measure any strain imposed on the part, directly in micro-inches per inch of strain.

Plastics materials are viscoelastic and their moduli of elasticity are generally quite low compared with wood, metals, ceramics, etc. Because of this, strength characteristics are largely dependent on time, temperature, and the environmental conditions. Since variations in these three factors will affect strain gage readings, the relationships between the factors *must be known* for accurate interpretation. To assist designers, Dow Plastics Technical Service Engineers have developed much data on Dow plastics. An example of their use in stress analysis follows, taking data from Fig. 1.

A hypothetical part for a creep application will be made from Tyril® 767; an application which will subject the part to a constant load (P), producing an initial strain (ϵ_1) on the part. The imposed strain can be measured with a strain gage, then stress calculated using:

$$S_1 = \epsilon_1 E_1$$

where: S_1 = Initial stress, psi

ϵ_1 = Initial strain in micro-inches/inch (from the strain gage)

E_1 = Apparent modulus, psi, at 0.1 hr. (Fig. 2)

If $\epsilon_1 = 2800$ micro-inches/inch $= 2800 \times 10^{-6}$

$E_1 = 5.35 \times 10^5$

Then $S_1 = \epsilon_1 E_1 = 2800 \times 10^{-6}$ in./in. $\times 5.35 \times 10^{-6} = 1500$ psi.

The amount of creep for any given time can then be determined using:

$$\epsilon_c = \epsilon_2 - \epsilon_1$$

where: ϵ_1 = Initial strain reading

ϵ_2 = Strain reading at time "t"

ϵ_c = Amount of creep

Let $\epsilon_1 = 2800$ micro-inches/inch

$\epsilon_2 = 3200$ micro-inches/inch

Then $\epsilon_c = (3200-2800)$ micro-inches/inch $= 400 \times 10^{-6} =$ 0.0004 inch/inch, the creep occurring at time "t".

One application of a strain gage to a plastics design problem is shown in Fig. 2. A freezer flip lid was studied to determine cause of breakage, the magnitude of stresses at failure, and at what period in the life of the part stresses were being imposed. Strain gages were bonded to critical areas of the flip lid, and measurements made of strain developed during assembly and actual service on the freezer. It was found that failure cracks (see Fig. 2) occurred because the mechanical and thermal applied stresses exceeded the design strength of the material. Further, the gages revealed that the stresses originated during both assembly and in service. The primary source of stress was discovered to be a rigid bond between metal and expanded plastic insulation. This prevented the plastic frame from acting independently, restricting its movement instead. The solution to the problem was self-evident, once the strain gages revealed the mode of stress development.

A few other applications of strain gages to plastics design and engineering problems are: measurement of coefficient of thermal expansion; measurement of Poisson's Ratio; elongation in test specimens; and stress analysis of bottle closures, home water filters, refrigerator parts, automotive parts, etc.

This study of strain gage applications is one of the continuing series of studies undertaken to assist plastics designers and engineers in the most effective selection and use of plastics materials. For information, and for data on Dow plastics materials, write THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Department 1802EX8.

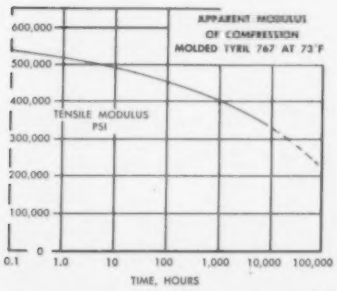

Fig. 1. Long-term data on Apparent Modulus of Tyril 767, for use in strain gage analysis.

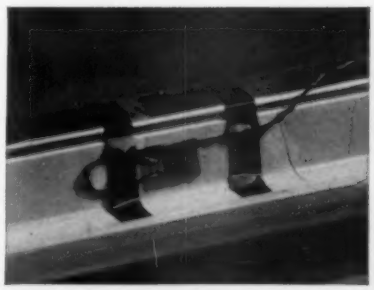

Fig. 2. Strain gage analysis of freezer lid reveals source of stress which caused failure.

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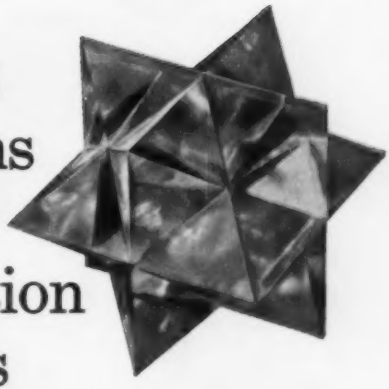

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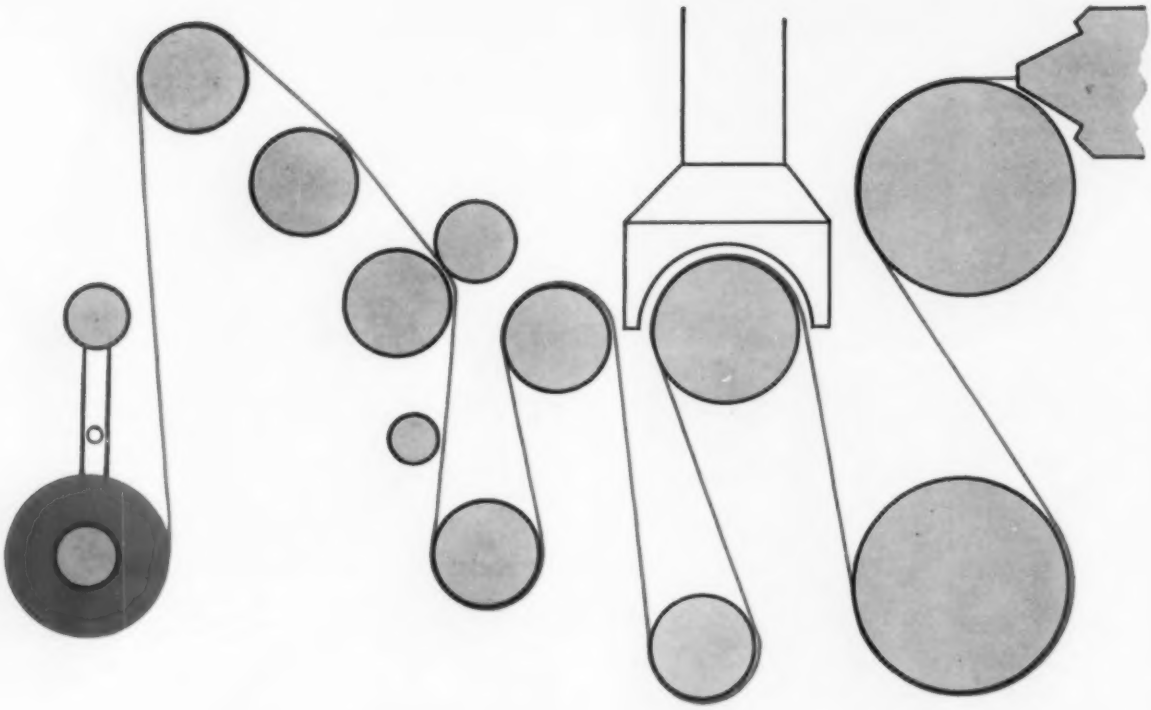

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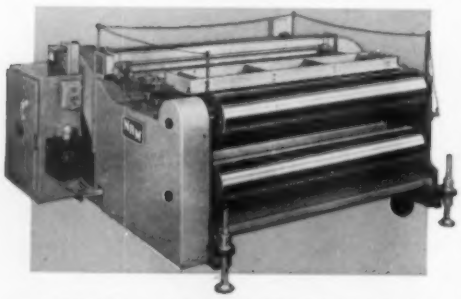

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SPEAKING OF EXTRUSION

A Practical Method

Predicting Extruder Performance With Plasticized PVC

A simple method for operation control, and for incoming inspection of compounded vinyl blends

Production control of extruder operation in many installations has not kept up with the improvements in extruder design. Competition between resin suppliers has provided for a healthy situation in which improvements are constantly being made in the types of material offered, as well as in the quality of the usual compounds.

One area in which there seems to be very little agreement is the production control of the extruder operation from one set-up to another. The classic example of a shift operator changing a perfectly good extruder operation to suit his personal settings is repeated many times, even though we are able to standardize other variables. If the foreman should suggest that the operator leave a standard setting constant, the operator has a good answer in that there are variables in the feed material. More specifically, variables in compounded vinyl stocks may be seen in extruder operation from time to time but the identification of these variables has not been easy.

This article describes a procedure in which processing speeds can be predicted from compounded vinyl blends by using a torque measuring device such as the Brabender Plastograph. A lab size intensive mixer with accurate power recording devices may also be used, although the author has found that the Brabender machine is exceptionally sensitive to the slightest change since the measurement is done directly from the torque requirements of the rotors.

An investigation into the compounding of various vinyl blends surprisingly pointed out that perfectly good materials of a given type were extruded at rates varying as much as 25%.

The variation in production rate of a coating extruder was first discovered on a small lab unit. Further checking proved that the variation could also be seen on production size equipment. A series of tests were conducted in order to attempt to identify the causes for the variances but this was not made clear. Some of the causes originally blamed for the variances were:

- Pellet size.
- Pellet shape (hot-cut versus cold cut).
- Extruder temperature profile.
- Extruder worm speed.
- Batch compounding procedure.

There was no easy identification of the variances; therefore, an attempt was made to set standards for processing speeds of coating extruders. It was found that standards could easily be set based on the curve profile obtained by using the Brabender Plastograph. Any variance in the materials compounded from a standard recipe could be identified from batch to batch. The rate variances expected in wire coating extruders could be scaled to the curve profile obtained from measurements in the Plastograph.

The speed at which a coating extruder operates with a given compound depends upon the rate at which the material will plasticize under a given set of extruder conditions. The variance discovered in these compounds was related to the amount of torque that could be applied by the Plastograph as well as to the time required to reach the peak torque. The procedure used in obtaining these graphs was to load a small charge into the heated box then quickly apply a ram while starting the chart travel.

This is understandable since an extruder is merely a device used to melt down and pump molten plastic through an orifice. Therefore, the faster the point of plastification is reached, the more efficiently an ex-

truder will operate since the pumping part of the operation may take place over a longer length of the screw. Work has been done along this line, using variable die pressures to obtain the optimum balance between plasticizing capacity and pressure capacity of extruders. (1.) But the interest here was in utilizing existing equipment rather than adding new equipment.

Figure 1 is a series of three curves showing the difference between three samples of an identical recipe of plasticized vinyl. A charge was loaded into the heated chamber of the plastograph and a loaded lid immediately is placed into position. The unit was started quickly and the rotors in churning the charge require a torque corresponding to the indication shown on the graph (*figure 1*). Referring to "pellets #1", the torque requirements were rather high and an initial peak was reached sooner than the other two samples. This indicates that the material plasticized quickly and that the rotors applied a greater amount of torque. The curve also drops very quickly to a fairly uniform level with narrow fluctuations. The rapid dropping of the indicator shows that the material is bonded into a plastic mass. "Pellets #2" is also a compounded sample processed in a manner different

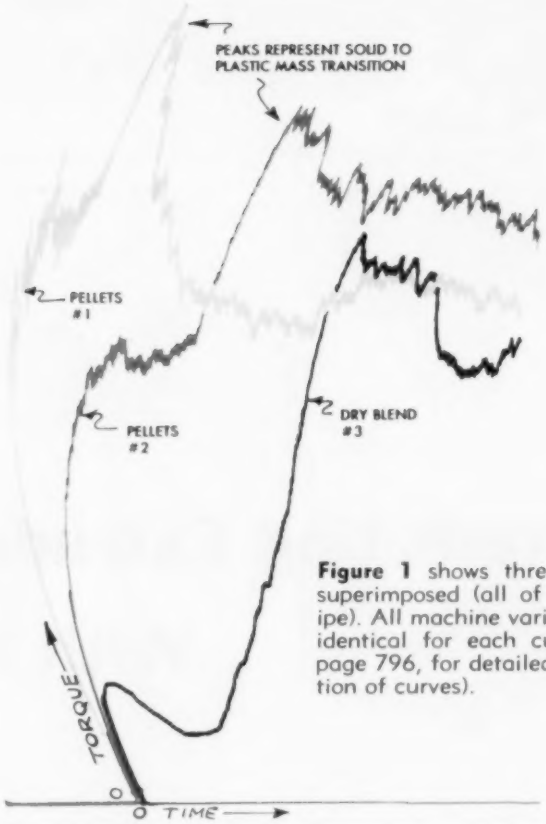

Figure 1 shows three graphs superimposed (all of one recipe). All machine variables are identical for each curve (see page 796, for detailed description of curves).

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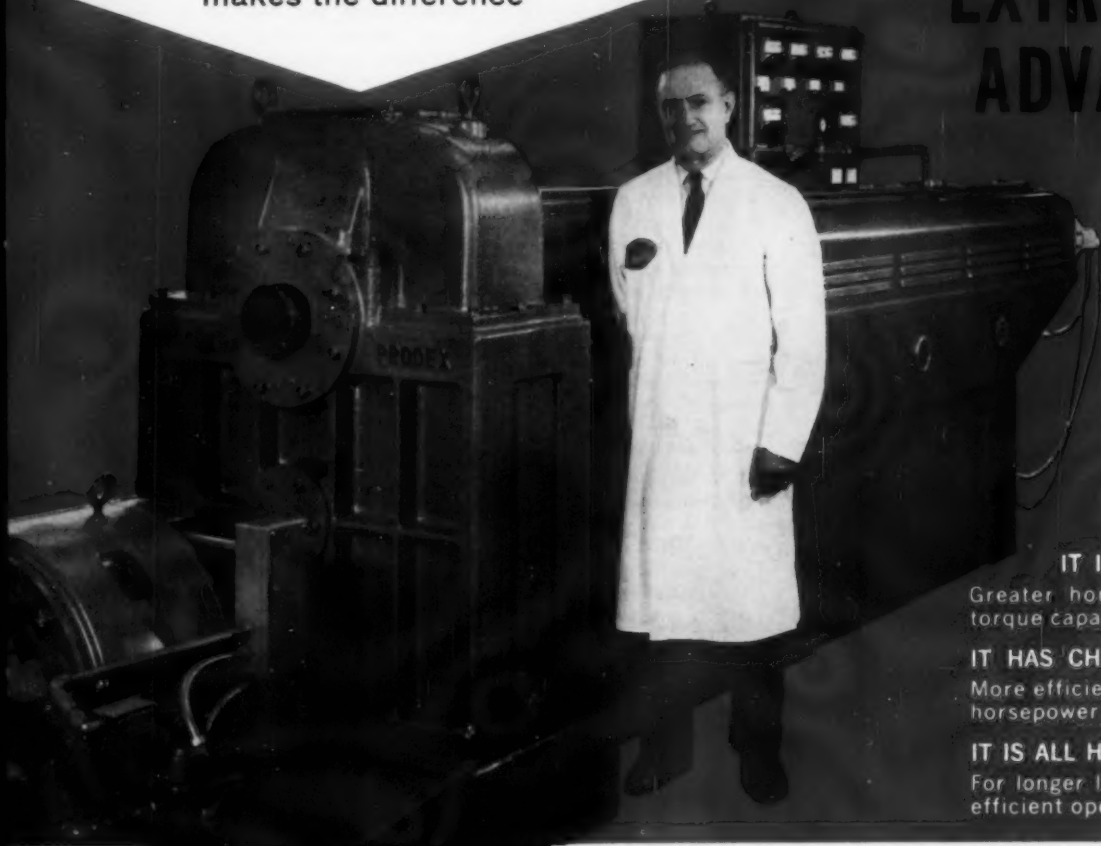

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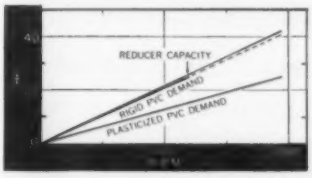
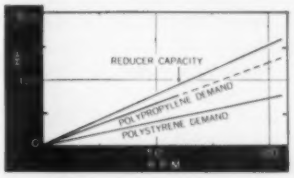


EXAMPLE 2.

The new 4½" PRODEX **HT** EXTRUDER, equipped with a 75 HP Dynamatic drive and gearing for 90 rpm max. screw speed, turns out 650 lbs/hr of high impact polystyrene without predrying. In order to run polypropylene M.I. 0.2, change gears for 65 rpm max. speed are used to deliver about 500 lbs/hr of this material. Without change gears, this machine would need a 125 HP drive, which would result in a substantial horsepower waste.



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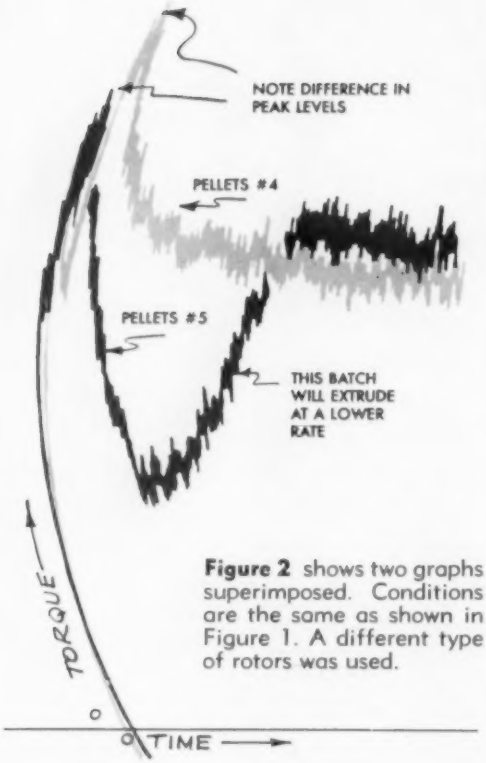

Figure 2 shows two graphs superimposed. Conditions are the same as shown in Figure 1. A different type of rotors was used.

from that used to process "pellets #1"; although both samples were acceptable extrusion grades based on usual standards. "Pellets #2" was delayed in reaching the first stage of partial plastification. The second stage of fully plasticized condition was also reached more slowly than with pellets #1. Dry blend #3 curve is used here just for comparison and represents the dry blend material used to make samples #1 and #2 by normal compounding procedures. The degree of torque and the amount of time actually required to reach these levels were not given in order to keep the comparison simplified.

As may be seen on *Figure 2*, product #4 reached the point of plastification quickly. The subsequent processing was uniform and at a reasonably low torque level. In contrast to this, the same material (pellets #5) compounded in a different manner required more time to reach the point of plastification and subsequent plastification was rather erratic.

Figure 3 shows the torque required to plasticize a standard compounded blend. A difference in curve profile can be noted due to a higher compounding temperature. These data were from a recipe different from the other charts. Pellets #6 were compounded at a higher temperature than pellets #7.

Figure 4 also shows the effect of processing temperature for still another formulation.

Most of the profiles have two peaks. The first peak is probably the effect of surface plastification. The second peak represents the transition from a solid to a plastic mass.

Two types of rotors were used and with the proper balance adjustment each arrangement gave the same assignable results. A very close relationship exists between the results of these tests and the coating extruder operation.

The reason for this relationship is clear when the coating extruder is considered merely as a plastificating device. In fact, the longer the extruder worm, the higher the throughput that may be expected since there is more time for the product to become plasticized and, therefore, greater pressure capacity. On the other hand, the faster a compound will flux, the higher the capacity of an extruder will be. In the valving of extruders one can visualize the point of solid to plastic transitions as being forced back towards the feed hopper. Similarly, a compound that will flux quickly will show rate and quality advantages over a slow fluxing compound in a given extruder set-up. The faster the compound is melted down, the more efficiently the extruder may be expected to operate. This does not mean that all compounded material should melt down at the fastest rate possible; rather, a method of checking anticipated extruder rates would be to correlate the level of torque application to the compound and the time required to reach the torque peak. This may be done by using the simple plastification rate and torque level pre-testing procedure. Each compound has a characteristic graph profile and each profile should be related only to a similar formulation. Note the differences in *Figures 1 and 3*.

Standard lab testing equipment such as a lab Banbury equipped with a recording Watt Meter will also yield similar information. However, the Brabender device gives a more direct reading since the measurements are from the drive motor housing deflection rather than through an electric circuit which may be dampened somewhat.

A procedure for utilizing this technique would be to set up a sampling program based on normal quality control procedures after good extruder production standards have been set. The control standards would be, in the case of the Plastograph, maximum and minimum curve profiles for both the peaks and the leveling off points. These curves could be obtained by first checking operating conditions of standard materials in production, then re-

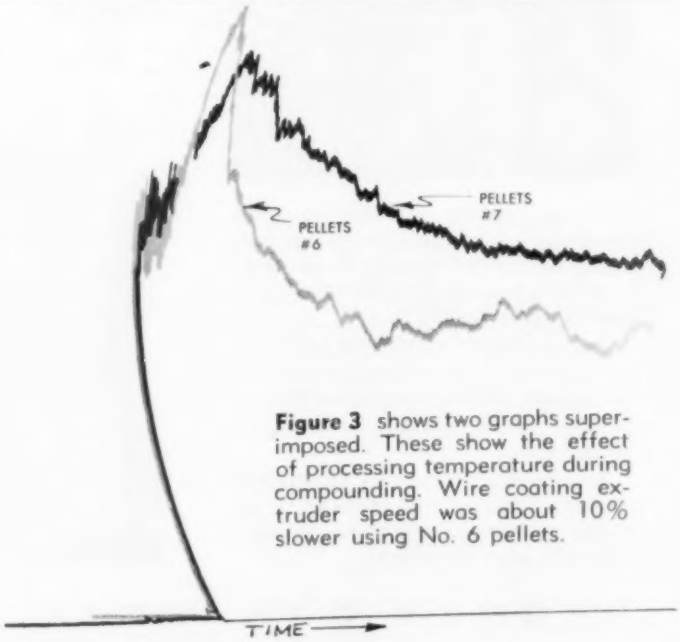

Figure 3 shows two graphs superimposed. These show the effect of processing temperature during compounding. Wire coating extruder speed was about 10% slower using No. 6 pellets.

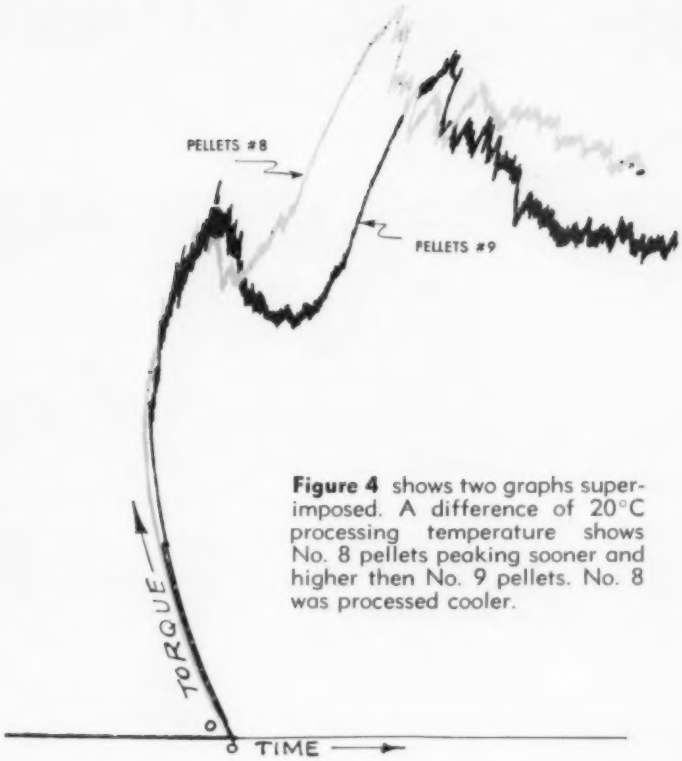

Figure 4 shows two graphs superimposed. A difference of 20°C processing temperature shows No. 8 pellets peaking sooner and higher then No. 9 pellets. No. 8 was processed cooler.

lating Plastograph profiles with plant production experiences. It is important that the plant conditions include standardized temperature settings as well as variances in wire sizes and/or die pressures.

The plant operations can be checked on laboratory sized coating extruders. Once the standards are set, an inspection procedure could be effected. If wide variances were found to be common, extruder settings or the anticipated extruder rates could be intelligently scheduled.

In conclusion, it is felt that this technique may be helpful in standardizing vinyl wire coating extruder operating procedures as well in providing for a method of incoming inspection of compounded vinyl blends.

Literature References

1. Maddock, B. H., Nalepa, H. J., Zurkoff, B., *Controlled Pressure (Valve) Extrusion*, Sixth Annual Signal Corps Wire & Cable Symposium December 1957.

edited by

Bruce H. Maddock,
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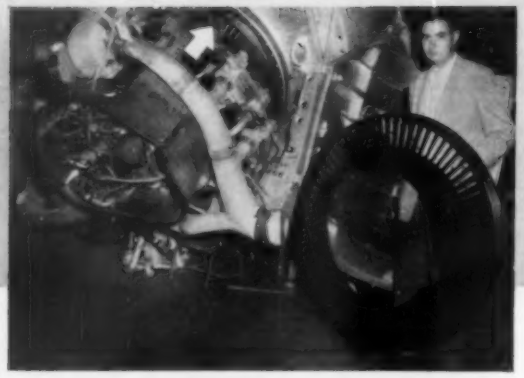

View of helicopter engine assembly shows position of contravane (arrow). In this location, the part is subjected to constant engine vibration. At right is an epoxy-glass fiber contravane, in excellent condition after 15 million cycles. It is produced for Sikorsky Aircraft, a division of United Aircraft Corporation by Hampden Brass and Aluminum Company, Fibermold Division.

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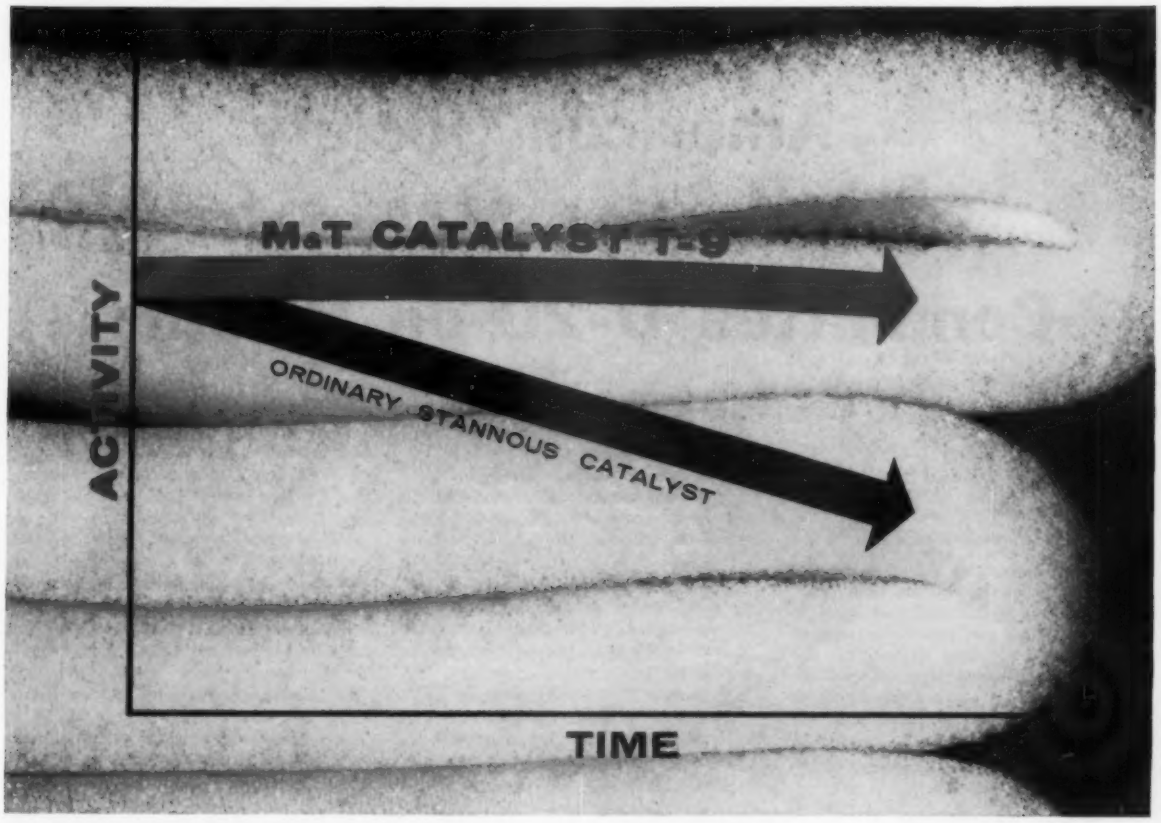

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STANDARDS FOR PLASTICS

American Society For Testing Materials Committee D-20 on Plastics

Scopes of committee, subcommittees and sections

Committee D-20 and its objectives

Objectives of the Committee are:

The development of test methods, specifications, recommended practices, nomenclature, and definitions pertaining to plastics; to their raw materials, components, and compounding ingredients; and to finished products made therefrom, such as sheets, rods, tubes, pipe, cellular materials, and molded or fabricated articles, including any associated research.

The subcommittees in Committee D-20 are classified as follows:

Methods Subcommittees
I, II, III, IV, V, VII, IX, XIII, XIV

Materials Subcommittees
XII, XV, XVI, XVII, XVIII, XIX, XX, XXII

Special Subcommittees
X, XI, XXI

Responsibility for test methods that are used or of interest to two or more materials subcommittees shall be assigned to methods subcommittees. Materials standards shall be assigned to materials subcommittees. Test methods that are used or of interest to only one materials subcommittee shall be assigned to that materials subcommittee, unless the materials subcommittee requests that they be assigned to methods subcommittees.

SUBCOMMITTEE I—MECHANICAL PROPERTIES:

The development of test methods for measuring mechanical properties.

Section A—Tensile Properties:
Test methods for measuring the properties of plastics when subjected to a tensile stress.

Section B—Impact Strength:
Test methods for measuring the energy required to fracture plastics when subjected to a rapidly-applied stress.

Section C—Fatigue Properties:
Test methods for measuring the resistance to fracture of plastics when subjected to rapidly-alternating stresses.

Section E—Shear Properties:
Test methods for measuring the properties of plastics when subjected to a shear stress.

Section F—Flexural Properties:
Test methods for measuring the properties of plastics when subjected to a slowly-applied stress in bending.

Section J—Bonding Strength:
Test methods for measuring the resistance to separation of the layers of a laminate when subjected to stress.

Section L—Strength Under Biaxial Stresses:
Test methods for measuring the strength of plastics when subjected to stresses from two directions.

Section M—Tear Strength:
Test methods for measuring the strength of plastics when subjected to stresses which results in a tearing-type failure.

Section N—Creep Properties:
Test methods for measuring the properties of plastics when subjected to sustained static stresses applied for a long period.

Section O—Dynamic Properties:
Non-destructive test methods for measuring the properties of plastics when subjected to alternating stresses or strains that are essentially sinusoidal with respect to time.

Section P—Stiffness of Films:
Test methods for measuring the rigidity of films.

Section Q—Indentation Hardness:
Test methods for measuring the resistance of plastics to indentation.

Section R—Surface Properties:
Test methods for measuring the coefficient of friction and blocking.

Section S—Abrasion Resistance:
Test methods for measuring the resistance of plastics to wear or surface damage.

Editor's Note

Because of the tremendous job that Committee D-20 has done in the field of standards for plastics, it was felt that readers of the SPE Journal who were not entirely familiar with this Committee—its makeup, its purposes, and its organization—would like to become acquainted with the vital work this Committee is doing. The article also shows how detailed a breakdown the Committee has—reflecting the almost superhuman task of developing standards for almost every field of endeavor in the plastics industry.

Section T—Compressive Properties:
Test methods for measuring the properties of plastics when subjected to a compressive stress.

Section U—Crack Propagation:
Test methods for measuring the crack propagation resistance in plastics when subjected to stress.

SUBCOMMITTEE II—RADIATION METHODS:

The development of test methods for exposure to nuclear and high energy radiation.

Section A—Definitions:
The selection of terms and development of definitions for them as required by Subcommittee II.

Section B—Dosimetry:
Standard dosimeters and test methods for measuring radiation.

Section C—Exposure Methods:
Procedures for irradiating plastics and electrical insulating materials.

Section D—Education:
The dissemination of information on the irradiation of plastics and electrical insulating materials.

Section E—Research:
The promotion and coordination of research that will facilitate the work of Subcommittee II.

SUBCOMMITTEE III—THERMAL PROPERTIES:

The development of test methods for measuring thermal properties.

Section A—Softening and Melting:
Test methods for measuring the temperature at which plastics change from a hard rigid state to a soft flexible one.

Section B—Basic Thermal Properties:
Test methods for measuring the basic thermal properties of plastics, such as, specific heat, thermal conductivity, coefficient of thermal expansion, and heats of transition.

Section C—Flammability:
Test methods for measuring the rate of burning of plastics, and the resistance of plastics to ignition.

Section D—Flow:
Test methods for measuring the flow properties of plastics at elevated temperatures.

Section H—Brittleness Temperature:
Test methods for measuring the temperatures at which plastics become brittle.

Section L—Ablation Tests:
Test methods for characterizing the behavior of plastics when subjected to erosion by gases at high temperature.

SUBCOMMITTEE IV—OPTICAL PROPERTIES:

The development of test methods for measuring optical and appearance properties.

Section D—Clarity:
Test methods for measuring the optical clarity of plastics.

Section E—Yellowness:
Test methods for measuring the degree of yellowness of nominally white or colorless plastics.

Section F—Hiding Power:
Test methods for measuring the degree of source-image obscuration by translucent plastics.

SUBCOMMITTEE V—Permanence Properties:

The development of test methods for measuring permanence properties.

Section A—Effect of Light:
Test methods for determining the resistance of plastics to light.

Section B—Effect of Heat:
Test methods for determining the resistance of plastics to heat.

Section C—Effect of Water:
Test methods for determining the resistance of plastics to water.

Section D—Effect of Chemicals:
Test methods for determining the resistance of plastics to chemicals.

Section E—Laboratory Weathering Tests
Test methods for determining the resistance of plastics to combinations of heat, light, water, or chemicals by laboratory tests.

Section G—Gas Permeability:
Test methods for measuring the rate at which gases flow through plastics.

Section H—Outdoor Weathering:
Procedures and conditions for exposing plastics outdoors.

Section J—Corrosivity:
Conditions and procedures for determining any tendency of plastics to cause corrosion of metals.

Section K—Stain Resistance:
Test methods for determining the resistance of plastics to staining from external sources.

Section M—Effect of Microorganisms:
Test methods for determining the resistance of plastics to microorganisms.

SUBCOMMITTEE VII—ANALYTICAL METHODS:

The development of test methods for analysis, identification, and general physical properties not otherwise assigned.

Section A—Physical Methods:
Test methods for measuring physical properties of plastics, such as, density, particle size, viscosity, and molecular characterization.

Section H—Spectroscopic Methods:
Test methods employing measurements of the absorption of ultraviolet, visible and infrared radiant energy by plastics.

Section K—Chemical Methods:
Chemical test methods for the analysis of plastics.

SUBCOMMITTEE IX—MOLDS AND MOLDING:

The development of procedures for molding and extruding test specimens, standard molds, and tests methods related to molding and extruding.

Section A—Compression Molding of Test Specimens:
Methods and dies for compression molding test specimens.

Section C—Shrinkage:
Test methods for measuring the differences in dimensions between the mold cavity and the molded plastic specimen or part and the evaluation of plastics by these methods.

Section D—Transfer Dies For Test Specimens:
Methods for making test specimens of thermosetting materials using transfer dies.

Section E—Temperature of Molds:
Procedures for measuring temperatures of molds for plastics test specimens.

Section H—Injection Processes:
Procedures for injection molding of plastics test specimens and the investigation of the variables involved in injection molding on the properties of the molded pieces.

Section J—Mold Release Properties:
Test methods for measuring the adherence of plastics to mold surfaces, of procedures for reducing this adherence, and of specifications for mold release agents.

SUBCOMMITTEE X—DEFINITIONS:

The development of nomenclature and definitions for terms.

SUBCOMMITTEE XI—EDITORIAL REVIEW:

The editorial review and revision of standards, except for definitions, to improve clarity, conciseness, composition, grammar, and form, and to insure uniformity in these matters.

SUBCOMMITTEE XII—POLYOLEFIN PLASTICS:

The development of specifications for polyolefin molding and extrusion compounds and resins, and tests unique to these materials.

Section A—Ethylene Plastics:
Specifications for ethylene plastics.

Section B—Propylene Plastics:
Specifications for propylene plastics.

Section C—Test Methods:
Test methods specific to polyolefin plastics.

Section D—Sample Preparation and Conditioning:
Procedures for preparing and conditioning samples of polyolefin plastics.

SUBCOMMITTEE XIII—STATISTICAL TECHNIQUES:

The development of experimental designs, evaluation procedures and sampling plans, and giving assistance to other sections and subcommittees in these matters.

Section A—Sampling:
Sampling plans for plastics.

Section B—Experimental Design:
Experimental designs for tests of plastics.

SUBCOMMITTEE XIV—CONDITIONING:

The development of methods for conditioning prior to and during test.

SUBCOMMITTEE XV—THERMOPLASTIC MATERIALS:

The development of specifications for thermoplastic compounds and resins, and their compounding ingredients.

Section A—Vinyl Chloride Plastics:
Specifications for vinyl chloride plastics.

Section B—Acrylic Plastics:
Specifications for acrylic plastics.

Section C—Styrene Plastics:
Specifications for styrene plastics.

Section G—Ethyl Cellulose Plastics:
Specifications for ethyl cellulose plastics.

Section H—Vinyl Chloride Resins:
The development of specifications for vinyl chloride resins.

Section I—Nylon Plastics:
Specifications for nylon plastics.

Section K—Plasticizers:
Specifications for plasticizers, and test methods specific to plasticizers.

Section L—Halocarbon Plastics:
Specifications for halocarbon plastics.

Section M—Cellulose Ester Plastics:
Specifications for cellulose ester plastics.

Section N—ABS Plastics:
Specifications for acrylonitrile-butadiene-styrene plastics (ABS).

Section P—Vinyl Dispersions:
Specifications for vinyl chloride resin dispersions and test methods specific to these dispersions.

SUBCOMMITTEE XVI—THERMOSETTING MATERIALS:

The development of specifications for thermosetting compounds and resins, and their compounding ingredients.

Section A—Phenolic Materials:
Specifications for phenolic plastics.

Section B—Amino Materials:
Specifications for amino plastics.

Section C—Polyester Materials:
Specifications for polyester plastics.

Section D—Allyl Materials:
Specifications for allyl plastics.

Section E—Epoxy Materials:
Specifications for epoxy plastics.

Section F—Urethane Materials:
Specifications for urethane plastics.

SUBCOMMITTEE XVII—THERMOPLASTIC PIPE AND FITTINGS:

The development of specifications for thermoplastic pipe, fittings, and valves, dimensional standards, recommended practices for joining, and test methods specific to these products.

Section A—Polyvinyl Chloride Pipe:
Specifications for polyvinyl chloride plastics pipe.

Section B—Cellulose Acetate Butyrate Pipe:
Specifications for cellulose acetate butyrate plastics pipe.

Section C—Polyethylene Pipe:
Specifications for polyethylene plastics pipe.

Section D—ABS Plastics Pipe:
Specifications for acrylonitrile-butadiene-styrene (ABS) plastics pipe.

Section G—Pipe Test Methods:
Test methods for thermoplastic pipe, fittings, and valves.

Section H—Polyvinyl Chloride Fittings:
Specifications for polyvinyl chloride plastics fittings and valves.

Section I—ABS Fittings:
Specifications for acrylonitrile-butadiene-styrene (ABS) fittings and valves.

Section J—Insert Fittings:
Specifications for thermoplastics insert fittings intended for use with flexible thermoplastic pipe.

SUBCOMMITTEE XVIII—REINFORCED PLASTICS:

The development of specifications for reinforced plastics and their components, and test methods specific to these materials.

Section A—Flat Sheets:
Specifications for flat reinforced plastics sheets, and test methods specific to these products.

Section B—Reinforced Pipe and Fittings:
Specifications for reinforced plastics pipe and fittings, and test methods specific to these products.

Section C—Corrugated Panels:
Specifications for corrugated reinforced plastics panels, and test methods specific to these products.

Section D—Laminating Resins:
Test methods specific to resins for use in reinforced plastics.

Section E—Reinforcements:
Specifications for solid reinforced materials intended for use in making reinforced plastics, and test methods specific to these materials.

Section F—Rods and Tubes:
Specifications for reinforced plastics rods and tubes, and test methods specific to these products.

Section G—Heat-Resistant Reinforced Materials:
Specifications for reinforced plastics intended for use at temperatures above 260°C (500°F), and test methods specific to these products.

SUBCOMMITTEE XIX—SHEETING:

The development of specifications for film and sheeting, and test methods specific to these products.

Section A—Vinyl Chloride Plastics:
Specifications for vinyl chloride plastics film and sheeting.

Section B—Polyolefin Plastics:
Specifications for polyolefin plastics film and sheeting.

Section C—Cellulose Plastics:
Specifications for cellulose plastics film and sheeting.

Section D—Acrylic Plastics:
Specifications for acrylic plastics sheeting.

Section E—Styrene Plastics:
Specifications for styrene plastics film and sheeting.

Section F—Test Methods:
Test methods specific to plastics film and sheeting.

SUBCOMMITTEE XX—CELLULAR PLASTICS:

The development of specifications for cellular plastics and test methods specific to these products.

Section A—Test Methods:
Test methods specific to cellular plastics.

Section B—Urethane:
Specifications for cellular urethane plastics.

Section C—Polyvinyl chloride:
Specifications for cellular polyvinyl chloride plastics.

Section D—Polyethylene:
Specifications for cellular polyethylene plastics.

Section E—Styrene:
Specifications for cellular styrene plastics.

Section F—Nomenclature:
Definitions for terms specific to cellular plastics.

SUBCOMMITTEE XXI—USA NATIONAL COMMITTEE FOR ISO/TC 61:

The execution of the responsibilities assigned to Committee D-20 by ASA for the USA activities in ISO/TC 61.

SUBCOMMITTEE XXII—PLASTICS FOR TOOLING:

The development of specifications for plastics used in tooling, and test methods specific to these products.

Section A—Ingredient Specifications:
Specifications for materials used to formulate plastics for making tooling.

Section B—Plastics Specifications:
Specifications of plastics used for making tooling.

Section C—Ingredient Test Method:
Test methods for ingredients used to formulate plastics for making tooling.

Section D—Plastics Test Methods:
Test methods for plastics used for making tooling.

Section E—Nomenclature:
Definitions for terms specific to plastics tooling.

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edited by
Frank W. Reinhart,
National Bureau of Standards

Celanese

PLASTICS IN DESIGN

Celanese plastics are reducing time, trouble and cost between design and better finished product. That's true of thousands of consumer and industrial products, where the unique properties of Celanese plastics offer many advantages . . . exceptional moldability . . . color and surface permanence . . . strength and light weight.

Celanese offers a variety of plastics

The design and function of countless items can be improved by the use of Celanese plastics which include . . .

FORTIFLEX A
. . . high density polyethylene

FLAME RESISTANT
FORTIFLEX A

FORTIFLEX B
. . . linear copolymers

FORTIFLEX C
. . . . medium density polyethylene

FORTIFLEX D
. . . low density polyethylene

FORTICEL
. . . cellulose propionate

ACETATE
. . . molding compounds

POLYESTER RESINS

ACETATE FILM

ACETATE SHEETING

POLYETHYLENE FILM

Let Celanese help with your Plastic Requirements...

We offer you complete technical service. Competent, experienced Celanese Representatives will gladly assist with any aspect of plastic selection, fabrication or application. And they're backed by one of the industry's most complete, modern plastics laboratories. Celanese warehouses and facilities are located at strategic points throughout the country to assure fast service wherever you are located.

Celanese
PLASTICS

Celanese

FOR STRONG, RIGID PARTS . . . ELECTRICAL AND

FORTIFLEX . . . a complete range of polyethylenes from .915 to .96 density

Celanese Fortiflex A and B are a family of linear polyolefins which differ from conventional polyethylene in both physical properties and methods of manufacture. Produced by a low temperature, low pressure method, Fortiflex A and B have the high crystallinity that results in different properties and performance . . . rigidity . . . resistance to high and low temperatures . . . low permeability . . . lustrous, less "waxy" surface . . . excellent tensile strength. What's more, all Fortiflex resins possess good chemical resistance . . . excellent electrical characteristics . . . good impact . . . easy moldability and colorability.

There are four basic Fortiflex groups . . . Series A, B, C and D. Each group is especially adapted to the requirements of specific end uses.

BLENDS—For many applications, a combination of Fortiflex of various densities is desirable. Celanese will supply these blends to match customer specifications, or will recommend one for your particular application.

PROPERTIES OF FORTIFLEX A60 AND B50

Properties related to Melt Index	Units	ASTM Method	PHYSICAL PROPERTIES A60-20	A60-70	A60-250	A60-500	A60-800	B50-20	B50-80 to B50-500
Melt Index	—	D1238-52T	0.2	0.7	2.5	5.0	8.0	0.2	0.8-5.0
Heat Distortion Temp., 66 psi	°F	D648-56	185	185	180	180	180	170-175	170-175
Impact Strength (1) Notched Izod (2)	ft. lb./in. notch	D256-54T	23	18	13	3	0.7	7	5-1
Tensile Strength, 0.2 in./min. (3)	psi	D638-52T	3,700	3,500	3,300	3,300	3,300	3,200	3,100
Elongation, 0.2 in./min. (3)	%	D638-52T	28	25	18	13	13	30	25-18
Environmental Stress Cracking Resistance, F50 Value	hr.	Bell Lab. (4)	190	30	6	3	—	2,000	(5)
Properties not related to Melt Index									
Density	g/cc	D792-50	0.96	0.96	0.96	0.96	0.96	0.95	0.95
Highest Use Temperature (6)									
Continuous	°F	—	180	180	180	180	180	—	—
Intermittent	°F	—	225	225	225	225	225	—	—
Softening Temperature (7)	°F	—	260	260	260	260	260	255	255
Stiffness in Flexure	psi	D747-50	140000	140000	140000	140000	140000	100000	100000
Hardness	Rockwell R	D785-51	40	40	40	40	40	40	40
	Shore D	D676-49	65	65	65	65	65	64	64
Mold Shrinkage (8)									
Length	in./in.	—	.010-.030	.010-.030	.010-.030	.010-.030	.010-.030	.010-.030	.010-.030
Width	in./in.	—	.010-.025	.010-.025	.010-.025	.010-.025	.010-.025	.010-.025	.010-.025
Flammability	in./min.	D635-44	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Water Absorption 24 hr. at 77°F	% gain	D570-54T	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Refractive Index	n_{D25}	D542-50	1.54	1.54	1.54	1.54	1.54	1.54	1.54

ELECTRICAL PROPERTIES

	Units	ASTM Method	Frequency (Cycles per Second)	Value
Dielectric Strength (Short time)	volts/mil	D149-55T	—	500
Volume Resistivity	ohm cm.	D257-54T	—	6×10^{15}
Dielectric Constant	—	D150-54T	1×10^{3}	2.35
			1×10^{6}	2.36
Dissipation Factor	—	D150-54T	1×10^{3}	0.0002
			1×10^{6}	0.0003
Loss Factor	—	D150-54T	1×10^{3}	0.0007
			1×10^{6}	0.0007

TYPICAL CHEMICAL RESISTANCE

	Value*
Acetic Acid, glacial	0.7
Sulfuric Acid 98%	0.0
Sodium Hydroxide 50%	0.0
Ammonium Hydroxide 28%	0.0
Carbon Tetrachloride	14.0
Methyl "Carbitol"	0.1
Water	0.0
Gasoline	6.0

*% increase in wt. after 30 days immersion at 80°F. Sample specimens were 1" x ¼" x ⅛".

FOOTNOTES

(1) Impact values observed on injection molded bars should not be considered indicative of practical impact values for molded items where other factors affect the impact value. While its impact value will be sufficient for most uses, Fortiflex B should be evaluated for each specific application.

(2) Injection molded specimens, ½" x ½" cross section, notch in the ⅛" face. A60-20, A60-70 and A60-250 specimens did not break. A60-500 and Fortiflex B50 copolymers exhibited partial or hinged breaks.

(3) Injection molded Type I specimens, ⅛" thick. Tensile strength and elongation data recorded at the first yield point.

(4) ASTM Standard on Plastics, Issue of February, 1957. Appendix, Page 831—Proposed Method of Test for Environmental Stress Cracking of Ethylene Plastics.

(5) Fortiflex B50-80 has an environmental stress cracking resistance F_{50} value of 160 hrs.

(6) Highest use temperature depends on part design, molding and service conditions, special formulations are available for continuous use at higher temperatures up to 212°F.

(7) Method of Karrer et al, Ind. Engr. Chem., Anal. Ed. 2, 96 (1930).

(8) Mold shrinkage depends on part design and molding conditions.

MOLDING COMPOUNDS

INDUSTRIAL PRODUCTS . . . HOUSEWARES . . .

FORTIFLEX A . . . linear polyolefins

Fortiflex A is available in both natural and colored molding powders. Five formulations provide a wide flow range.

A60-20 possesses the highest impact strength, stress cracking resistance and low-temperature strength of the A series, and requires somewhat higher process temperatures. It's recommended for extrusion, calendering, blow molding or injection molding of very small parts requiring maximum physical properties.

A60-70 is a general-purpose resin. It's recommended for injection molding of small parts with limited surface area; for extrusion, calendering, blow molding, and as a rubber compounding additive.

A60-250 is suggested for intermediate-sized injection molded articles where better moldability and improved surface finish are required.

A60-500 possesses the best moldability for large-area moldings and applications where maximum processability and high surface gloss are required.

A60-800 is used primarily as a blending component with Fortiflex D polyethylene. It offers substantially improved flow characteristics with reduced impact strength compared to other resins in the Fortiflex A series. It can be used in blends, single-use containers, or items requiring low impact strength such as certain toys and novelties. It is not recommended where stress cracking is a problem.

TYPICAL APPLICATIONS: housewares, appliance, electrical and automotive parts, filaments for textiles and rope, bottles and containers, toys, industrial parts and protective helmets.

FLAME RESISTANT FORTIFLEX. Celanese offers specially formulated flame resistant variations of Fortiflex A60-70, A60-250, and A60-500. These formulations are opaque, self-extinguishing, high-density polyethylenes with a specific gravity of 1.04. Their stiffness, hardness and tensile strength are approximately the same as the standard resins', although heat distortion values under 66 psi are slightly lower and impact strength is somewhat reduced. Burning rate or flammability is reduced to the point where they can be classified as non-burning materials under ASTM D-635-44.

FORTIFLEX B . . . linear copolymers

The Fortiflex B series offers a family of resins with an extremely broad range of properties and special advantages. They make it possible to upgrade many applications now employing other thermoplastics, and open up many new fields of application for plastics.

Fortiflex B is an excellent injection molding plastic and provides outstanding stress crack resistance. Processability of Fortiflex B resins is somewhat improved over the Fortiflex A series resins when compared on a melt index for melt index basis. Thus, cycle time for a given part may be less for these resins compared to Fortiflex A, since their cold point and viscosity are lower.

In tests under a static load, properly oriented filaments of the new polymer show reduced tendency to stretch.

APPLICATIONS: filaments for rope and outdoor furniture webbing, wire covering, blown bottles and containers, and pipe.

Applications for injection molding include: containers for stress-active agents, drum plugs, fittings and couplings, thin-walled moldings, large area moldings, insert moldings, bottle caps and closures.

The Fortiflex B series has opened new prospects for the blow molding of bottles and hollow-ware.

FORTIFLEX C . . . medium density polyethylenes

Fortiflex C is a medium density resin presently offered only in a .934 density and 1.7 melt index. It is midway in stiffness between the softer type low density polyethylenes and the rigid type Fortiflex A and B resins. Fortiflex C is available in three different formulations for film, paper coating and pipe extrusion.

The film formulation is ideal for the extrusion of film for overwraps for stationery and bread and provides excellent clarity in chill roll extrusion. The paper coating formulation gives optimum greaseproofness at ¾ mil thickness, and it passes MIL-B-121B at 12 pounds per ream. The pipe formulation is sold only in black. It is NSF approved, meets the proposed 1960 revision of CS-197 Type II pipe, and has a compounded density of .942.

FORTIFLEX D . . . low density polyethylenes

The Fortiflex D series of polyethylene resins is available in a range of densities from .915 to .924 and in a variety of melt indices which provide a line of resins ideal for injection and blow molding as well as the extrusion of film, pipe, wire covering and paper coating. These resins range from moderately stiff materials at the top of the density range to the softest low density polyethylenes commonly in use today.

Within this line of resins are materials specially suited to large, medium and small area injection molded toys, housewares, closures and industrial parts; coatings for locker wrapping paper, milk cartons, laminating to aluminum foil and acetate, multi-wall bags, kraft and cellophane. Also available are resins for NSF pipe that meet the proposed 1960 revision of CS-197 Type I, wire coverings for tree and line wire and power cable as well as cable jacketing and primary insulation which meet ASTM D1248-58T, Type I, Grade 4 and Federal Specifications LP-590, Type I, Grade 7. Film resins include materials for blown or chill roll film for freezer bags, produce bags, garment bags, soft goods overwraps, and general purpose films. Blow molding resins cover both general purpose requirements in squeeze bottles and critical packages where superior stress cracking resistance is required.

CELANESE POLYESTER RESINS . . . for boats . . . auto and truck bodies . . . housings . . . tanks and tank linings

Celanese polyester resins are thermosetting liquids; 100 percent polymerizable which do not liberate volatile by-products during cure. The Marco series of base resins are available in blends with styrene, vinyl toluene, methyl methacrylate or diallyl phthalate monomers in a range of varying viscosities. These resins can be readily cured at elevated temperatures employing peroxide type catalysts at moderate to contact pressure. With the addition of accelerators, it is possible to affect rapid cure at room temperature thus eliminating the need for heating equipment.

The simple fabricating techniques required to use Celanese polyester resins, combined with the outstanding properties of the end products, such as high strength, light weight, resistance to moisture, excellent weathering, and chemical resistance have led to their use in the production of a broad range of items in the industrial, construction, transportation and decorative fields. Included are such products as auto bodies, aircraft parts, boats, buttons, corrugated and flat sheeting, ducting, fishing rods, furniture, housings, shelters, tanks, trays, tote boxes, trophies and many others.

FORTICEL . . . cellulose propionate

Its excellent *balance* of desirable properties makes Forticel distinctive among thermoplastics. Its combination of toughness and good flexural strength is unique among cellulose ester plastics. And it is free of objectionable odor.

The high impact strengths of Forticel occur at moderate plasticizer levels, where its other fine characteristics, such as dimensional stability and stiffness are also optimum. No other cellulose plastic of similar general properties has less humidity expansion. Its low water absorption results in stability against warpage. And Forticel has considerably more resistance to weathering than cellulose acetate, and is very similar to cellulose acetate butyrate in this respect.

Forticel provides an exceptional luster on molded surfaces, obtainable on a fast cycle—in some items the fastest of all the cellulosics. A free flowing plastic, it can be injection molded with great ease, and lends itself to restricted gating and complicated mold layouts. Its superior flow insures practically invisible weld lines where two streams of plastic meet in the die. Forticel eliminates problems of flow around mold pins.

Forticel is produced in four series of formulas offering different flow ranges and end-use advantages. It is offered in a range of transparent, translucent and opaque colors.

TYPICAL APPLICATIONS: pens, telephone housings, automotive parts, personal items, business machine keys, vacuum cleaner attachments, handles, small equipment housings.

ACETATE . . . molding compounds

Economical, versatile Celanese Acetate is a widely used cellulosic plastic. In toughness, acetate can seldom be matched by any other plastic in its price bracket. It has high impact strength, rigidity, a hard surface, satisfactory dimensional stability for a wide range of applications. What's more, acetate is free of objectionable odor and has relatively good temperature stability. The XK series is formulated entirely of ingredients considered acceptable for use in contact with foods by the Food & Drug Administration. Dielectric properties are good. The plastic is unharmed by common hydrocarbons such as gasoline, benzine and oils.

Acetate has excellent moldability, and molding temperatures are not critical. The plastic is free-flowing, which minimizes the problem of weld lines, and is recommended for applications incorporating metal inserts. With the aid of pre-plasticizing machines, heavy parts can be molded in one cavity, or family molds can be used.

Acetate molds with an excellent surface finish, and it is easily fabricated. Parts may be cemented together to give a bond as strong as the original pieces. Formulations can be widely varied in properties by use of various types and amounts of plasticizers.

Acetate is produced in a number of formulations—including flame resistant material in a broad range of flows. It is offered in a practically limitless variety of transparent, translucent and opaque colors, as well as crystal clear. The flame resistant XFA and XFB formulations have achieved wide acceptance in the molding of appliance parts and housings where Underwriters approval may be a problem.

TYPICAL APPLICATIONS: toys, shoe heels, appliance housings, toilet seats, jewelry, tool handles, sun glasses, brush backs.

Celanese SHEETI

ACETATE SHEETING . . . for formed parts . . . displays . . . packaging . . . safety shields

Celanese Acetate sheeting is a thermoplastic material produced by solvent casting and dry extrusion for use in a wide range of applications. The physical and mechanical properties for which it is most noted include:

- **Ease of fabrication**
- **Easily formed by all conventional methods**
- **Rigidity and toughness**
- **Crystal transparency**
- **Good Aging**
- **Excellent printability**
- **Grease resistance**
- **Wide range of colorability**

CAST SHEETING. Cast sheeting is produced in several formulations in continuous length rolls, gauges 0.003″ through 0.020″. It is manufactured in clear transparent only, but can be surface tinted with transparent colors. Cast sheeting has a grainless surface of high perfection and is recommended for applications requiring the best optical clarity and greatest rigidity. For special applications cast sheeting can be supplied with a continuous matte surface. Although produced in continuous lengths, cast sheeting can also be supplied in stock size or cut-to-size sheets.

EXTRUDED SHEETING. Extruded sheeting is produced in a wide range of formulations. It is available in continuous length rolls, gauges 0.003″ through 0.030″. It is also produced in sheets 0.003″ through 0.250″. The wide range of formulations assures proper selection of a suitable material for a specific application.

Extruded sheeting is manufactured in clear transparent and in an unlimited range of transparent to opaque colors. This sheeting is economically priced and can also be supplied in a variety of finishes. The most common finishes are "as extruded," high polish, and matte.

APPLICATIONS for Celanese Acetate sheeting include: Transparent containers and protective covers. Contour, blister and skin-type packages. Personal accessories such as costume jewelry, buttons, handbags. Optical frames, face shields, safety goggles, and safety devices. Transparent sheets for printing, or metallizing. Loose-leaf insert folders. Toys, games, and lampshades.

ACETATE FILM . . . for packaging . . . graphic arts . . . magnetic tape . . . separator sheets

Celanese Acetate film is an economical thermoplastic material widely used for its sparkling clarity and ease of processing. Acetate is readily slit, cut, laminated, metallized and printed. High speed and automatic operations may be used. It can be sealed rapidly with heat and solvents, has a long shelf life, and does not block under most conditions of storage. Available in thicknesses from 0.0005″ to 0.002″, these materials are offered in a broad range of widths, continuous lengths, and cut sheets in clear transparent.

Celanese Acetate film is manufactured in two types: cast and extruded. These are generally similar in appearance and properties, and can be used interchangeably in many applications. The cast type is a premium quality film outstanding for its perfection of surface, grainless transparency and uniformity. Both film types are produced in a number of formulations to fit specific applications. The excellent physical and mechanical properties of Celanese Acetate films provide many important advantages, such as:

- **Excellent transparency**
- **Long shelf life**
- **Dimensional stability**
- **High permeability to gases**
- **Mold retardance**
- **Resistance to fogging**
- **Excellent greaseproofness**
- **Ease of fabrication**
- **Exceptional printability**

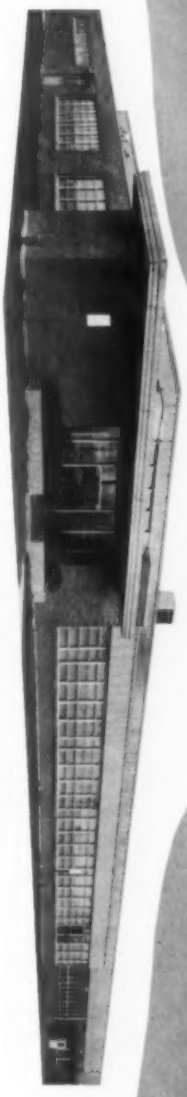
APPLICATIONS for Celanese Acetate Film include: laminations of many types, windows for cartons and envelopes, backing for magnetic recording tape, pressure sensitive tape, gold stamping foil and decorative ribbons, overwraps for packaging fresh produce and long shelf life merchandise. It is also used extensively for electrical insulation, metallizing, and as separator sheets in the manufacture of polyester resin panels.

F.D.A. ACCEPTANCE. Certain formulations in both sheet and film are compounded entirely of ingredients acceptable to the Food and Drug Administration in connection with food packaging.

TING AND FILM

TYPICAL PROPERTIES OF ACETATE SHEETING

Property	Test Method	Units	Cast Sheet L Series .003" gauge to .010" gauge	Extruded Sheet S Series .010" gauge
Tensile Strength	D882-56-T Method B	psi	10,500–12,000	7,200–8,000
Elongation	Method B	%	38–45	67–73
MIT Fold Endurance	D643-43 Method B	No. of double folds	10–100	12–20
Flammability Rate	D568-56T	Rating	Non-burning–Self-extinguishing	Burning–Self-extinguishing
Heat Shrinkage	48 hr. at 120°F.	%	0.17–0.25	0.10–0.45
	48 hr. at 245°F.	%	0.8–2.2	3.3–5.2
Total Light Transmission	D672-45T	%	91–92	91
Specific Gravity	D792-44T at 23°/23°C.	—	1.31	1.29–1.32
Water Vapor Transmission	F96-53T	g/24 hr./sq. m.	—	—
	0-50% RH, 73°F.		13–45	25–30
	50-100% RH, 73°F.		65–200	65–75
	0-90% RH, 100°F.		170–550	160–200



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FORMULA	ACETATE FILM* Cast P900 Series	ACETATE FILM* Extruded S600 Series	POLYETHYLENE FILM
Thickness Range, inches	0.0007–0.002	0.0005–0.002	0.0004–0.006
Specific Gravity	1.26–1.31	1.29–1.31	0.910–0.925
Tensile Strength, psi	7,000–13,000	7,000–10,000	1,350–2,500
Elongation, %	15–42	25–55	50–600
Softening Temperatures**			
°C.	125–175	140–150	110
°F.	260–350	285–300	230
Heat Shrinkage, %			
48 hr., 60°C. (140°F.)	0.05–2.5	0.1–1.5	—
48 hr., 116°C. (240°F.)	0.9–7.0	2.0–5.0	
Moisture Absorption, % 24 hr., 0% RH, plus 48 hr., 90% RH.	3.5–8.5	3.5–4.5	NIL

*All tests were made after the samples had been conditioned for 24 hours at 50% relative humidity and 25°C. (77°F.), and the tests were made under the same conditions.

**Softening Temperature—Temperature at which sample becomes limp when heated on a polished copper block at rate of 15°C. per minute. Samples conditioned before testing for at least 24 hours at 50% RH. and 23°C.

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POLYMER SCIENCE

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National Bureau of Standards

Polymer Decomposition: Thermodynamics, Mechanisms, And Energetics

Part I

The availability of polymers that are stable at high temperatures would greatly enhance the capabilities of modern technology. Considerable research effort is now being directed towards the discovery or synthesis of such materials. Guidance for the production of new polymers and the optimum use of existing polymers depend to a great extent on the limited mechanistic, energetic, and thermodynamic data now available. In all three categories there is really only a relatively small amount of information in the literature on polymers. One of the reasons for this is that a polymer is never in a strict sense a unique single chemical entity since all such materials have a molecular weight distribution. Although this can be ignored or neglected in many cases, there still remains the question as to whether or not a polymer can be prepared as a pure substance in a strict chemical sense.

Purities greater than 99% are difficult to achieve. For instance, the removal of solvents often requires heating the polymer to decomposition temperatures [1], and the removal of water is often equally difficult [2]. Polydiolefins such as natural rubber must contain antioxidants or they rapidly oxidize in air. The techniques for handling and characterizing polymers have, however, become highly developed, as have the methods for synthesizing and preparing polymers. It would appear, then, that more emphasis on investigations in the thermodynamic and mechanistic areas is desirable and needed in order that progress may continue and not be impeded by lack of fundamental information. Thermodynamic data pertinent to polymers are relatively plentiful only for hydrocarbons. For other organic materials and fluorocarbons there is a rather sparse or meager amount of data. The purpose of this discussion is to survey available information relevant to the mechanisms of decomposition of polymers and their thermal stability.

Thermodynamics of Polymer Decomposition

For complex overall reactions of different types it is well known that thermodynamics quantities do not in general allow one to predict how a material will decompose thermally. One must rather rely on the existing knowledge and theory of elementary processes. For an illustration of this point we have calculated the standard changes in heat content, entropy, and free energy at 25°C for several hypothetical possibilities for the decomposition of polyethylene and polytetrafluoroethylene (see *Table 1*).
The values for polytetrafluoroethylene may be in error by a few kilocalories because of the occurrence of a transition [5] near room temperature. However, the magnitude of the results for the different modes of decomposition is such that this error can have little effect on our conclusions.

It is seen at once that the decomposition of both polymers to carbon and methane or tetrafluoromethane is exothermic and has a high negative free-energy change (ΔF). In the case of the fluorocarbon polymer, decomposition in this way might be expected to occur with almost explosive violence. However, neither polymer actually decomposes in such a manner under most of the conditions so far studied. Since they exist for long periods of time, even at temperatures considerably above room temperature, it is clear that they are in a sense metastable. From the thermodynamic data alone, the prediction of the actual mode of decomposition would therefore be extremely difficult. The reactions d and f are the observed modes of degradation when the materials are heated in a vacuum until decomposition occurs. Since polyethylene decomposes to give a large variety of alkenes, we have used data for a n-C_{36}-1-ene in calculating values for the observed decomposition.

It is interesting to note that at 25°C the decomposition of polyethylene to the alkenes involves a negligible change in heat content (ΔH), while that of polytetrafluoroethylene going to its monomer has a large endothermic change of 46 kilocalories. Values such as those listed in *Table 1* are useful in anticipating decomposition products under extreme conditions. For instance, under atomic irradiation polyethylene decomposes to give appreciable hydrogen and low boiling hydrocarbons, while polytetrafluoroethylene does produce some tetrafluoromethane. There is then a trend in irradiation processes towards

Table 1. Thermodynamic Quantities for Decompositions of Polyethylene and Polytetrafluoroethylene [3-9]

		ΔH kcal/mole	ΔS cal/mole/°K	ΔF kcal/mole
~~CH$_2$CH$_2$~~	$\xrightarrow{a}$ CH$_2$=CH$_2$	22.35	34.27	12.19
	$\xrightarrow{b}$ 1/3 C$_6$H$_6$ + H$_2$	16.46	34.39	6.23
	$\xrightarrow{c}$ 2C (GRAPHITE) + 2H$_2$	9.85	45.51	−4.09
	$\xrightarrow{d}$ n-ALKENES [CH$_3$(CH$_2$)$_{33}$CH=CH$_2$]	1.09	2.16	0.48
	$\xrightarrow{e}$ C (GRAPHITE) + CH$_4$	−8.04	27.59	−16.23
~~CF$_2$CF$_2$~~	$\xrightarrow{f}$ CF$_2$CF$_2$	46	45	33
	$\xrightarrow{g}$ 2C (GRAPHITE) + 2F$_2$	194	71	172
	$\xrightarrow{h}$ C (GRAPHITE) + CF$_4$	−27	35	−38

the negative free energy reactions; c and e for polyethylene and h for polytetrafluoroethylene. One would also expect that rapid exposure to very high temperatures would overcome mechanism restrictions and favor decompositions with the higher negative free energy. The existence of numerous possibilities for net decompositions other than those depicted in *Table 1* or other than those for which data are available limits the number of conclusions we can draw without reservations.

Ceiling Temperatures

A very useful concept of importance to polymer stability and the mechanisms of polymer decomposition and polymerization is that of the ceiling temperature which is the temperature at which the rate of propagation is equal to the rate of depropagation. It is arrived at by considering the thermodynamics of the equilibrium shown:

$$R^{\bullet}_i \underset{k'_2}{\overset{k_2}{\rightleftarrows}} R^{\bullet}_{i-1} + M \qquad (1)$$

where $R^{\bullet}_i$ represents the number of polymeric free radicals or ions with degree of polymerization i which may either add or release a monomer unit, M. The reaction constants, k_2 and k'_2, represent the depropagation and the propagation reactions, respectively. The ceiling temperature, T_c, is defined as the temperature where, when M is unity, i.e. at 1 atmosphere pressure or at 1 mole per liter concentration:

$$k_2R^{\bullet} = k'_2R^{\bullet}M \qquad (2)$$

or where the equilibrium constant for the system is one, $R^{\bullet}$ representing all radicals in the system. The values of T_c then may be approximated, as shown by Dainton and Ivin [10], from the standard values for heat content and entropy change for polymerization and the relationship:

$$T_c \cong \frac{\Delta H^{\circ}p}{\Delta S^{\circ}p}$$

Experimental measurements on such equilibria have also led to ceiling temperature values [11, 12, 13, 14].

Estimates of the ceiling temperatures now available for specific polymers are listed in *Table 2*. We sometimes ascribe a decomposition temperature to each polymer which is defined as the temperature at which its rate of decomposition in a vacuum is one percent per minute. The values of the ceiling temperatures are in the same sequence as the decomposition temperature T_d or thermal stabilities of the compounds listed in *Table 2*. In most cases, the ceiling temperature is below the decomposition temperature. In the case of polyethylene they are equal; however, it should be noted that polyethylene does not thermally decompose into monomer.

Polytetrafluoroethylene, as usual, is in a class by itself and has a ceiling temperature higher than its decomposition temperature. This implies a relatively high thermal stability of the radical compared to the stability of the carbon-carbon bonds in the polymer. Polymers are for the most part more thermally stable than one would expect on the basis of the ceiling temperature concept. This is because, in thermal decomposition, the production of the intermediate free radicals is a rather difficult process, presumably the dissociation of certain bonds.

Radicals may be formed through the agency of ultraviolet or atomic radiation as well as simple thermal dissociation. Which group or structure dissociates is one of the very pertinent questions important to understanding both the mechanism of decomposition and the thermal stability of polymers.

Mechanism of Polymer Decomposition

The thermal decompositions of polymers so far investigated appear in the main to be chain reactions involving free radical intermediates [15]. There are some exceptions [2, 16], however, such as polyamides and polyesters, where the presence of moisture and traces of acid polymerization catalysts lead to non-chain ionic hydrolytic mechanisms. The essential features of the polymer decomposition indicate mechanisms of the Rice-Herzfeld type [17], which have been used extensively to elucidate organic decompositions in the gas phase [18]. The treatment of polymer decomposition in terms of such a mechanism has been carried out [19, 20], although the polymeric character of the system introduces complications. For some variations of

Table 2. Decomposition and Ceiling Temperatures

Polymer	T_d, °C	T_c, °C	Reference
Tetrafluoroethylene	510	580	[9]
Ethylene	400	400	[4, 10]
Propylene	380	300	[10]
Styrene	360	230	[10]
Methylmethacrylate	330	220	[14]
Methacrylonitrile	>200	177	[11]
Isobutylene	340	50	[10]
Alphamethylstyrene	290	7	[10, 12, 13]
Formaldehyde	>100	10 to 58	[10]

the mechanisms, electronic computation is required [21].

Treatment of polymer decomposition requires the following elementary processes:

Initiation:

$$\sim CH_2CHXCH_2CHX \sim \xrightarrow{k_1} \sim CH_2CHX\cdot + \sim CHXCH_2\cdot$$

Depropagation:

$$\sim CH_2CHXCH_2CHX\cdot \xrightarrow{k_2} \sim CH_2CHX\cdot + CH_2{=}CHX$$

Intermolecular transfer:

$$\sim CH_2CHX\cdot + \sim CH_2CHXCH_2CHX \xrightarrow{k_3} \sim CH_2CH_2X + \sim CH_2\dot{C}XCH_2CHX \sim \rightarrow \sim CH_2CX{=}CH_2 + \sim CHX\cdot$$

Intramolecular transfer:

$$\sim CH_2CHXCH_2CXCH_2CHX\cdot \xrightarrow{k'_3} \sim CH_2CHXCH_2\dot{C}XCH_2CH_2X \rightarrow \sim CH_2CHX\cdot + CH_2{=}CXCH_2CH_2X$$

Termination:

$$2 \sim CH_2CHX\cdot \xrightarrow{k_4} \sim CH_2CH_2X + \sim CH{=}CHX$$

Initiation leads to polymer radicals which can either depropagate to give monomer or transfer. There are numerous distinctive ways that initiation can conceivably occur, each of which has important consequences for the overall thermal decomposition. Whether initiation is induced thermally or by radiation, there is the possibility of preferred initiation at the end, at some other specific site, or at random. Unless a polymer initiates at random, it is conceivable that its thermal stability can be improved by eliminating special structures that dissociate easily. Otherwise, since the reactions involve chain mechanisms, inhibition is theoretically possible [22, 23]. However, the product of inhibition must be at least as thermally stable as the polymer, and the inhibiting substance must not also act as an initiator.

The depropagation has been previously mentioned in connection with the ceiling temperature. The intermolecular transfer step competes with depropagation, and the relative success of one over the other determines to a great extent the behavior of the decomposition. For instance, if depropagation overwhelms intermolecular transfer, the molecular weight of the polymer does not change during the course of pyrolysis, and the rate of volatilization is directly proportional to the mass of polymer remaining. In polymer decompositions that occur mainly in the condensed phase and rarely in solution, the intermolecular transfer reaction is favored. This is evident from the low yield of monomer ($\sim$ 0.1%) from polyethylene, whereas n-paraffins in the gas phase give up to 40% ethylene [24].

In polyethylene, it is clear that transfer overwhelms depropagation. With linear polyethylene, the rate-versus-conversion curves show maxima [25], whereas with branched polyethylene the maxima do not occur. This difference suggests less intermolecular transfer and more intramolecular transfer as the degree of branching increases [26]. A similar effect of branching was observed for polypropylenes [26]. Intramolecular transfer, except that it does not produce monomer, affects the kinetics in the same manner as depropagation.

The operation of transfer reactions, besides being evident from the overall pattern of behavior for the polymers so far investigated [15], has been demonstrated in the case of polystyrene by the use of the deuterium isotope effect [27]. With deuterium in the alpha position of the monomer unit, the polymer, upon thermal decomposition, gives a higher yield of monomer, and the molecular weight of the polymer decreases more slowly. The higher monomer yield would result if the rates of either or both of the intermolecular and intramolecular transfer reactions were decreased; however, the effect on the change in molecular size indicates that intermolecular transfer does occur.

The termination step has been commonly assumed to be as shown, i.e., disproportionation. Although unimolecular terminations of various types are conceivable, the limited experimental evidence so far available indicates bimolecular termination.

Mechanism of Initiation

Of considerable importance to polymer stability is the mechanism of initiation. The idea of weak links in polymer degradation seems attractive at first sight since the chain model for treating polymers has been extremely useful in other areas of polymer chemistry. However, since the decomposition of polymers in the main are chain reactions, simple weak-link theories are unjustified for the overall process. Rather, it is more reasonable to use the concept of an initiator, such as the role of benzoyl peroxide in many addition polymerizations.

A priori, there are numerous ways of initiation conceivable. Most possibilities capable of experimental attack are within the scope of two basic questions: 1. Does initiation occur through the agency of impurities or by the dissociation of the normal bonds of the polymer? 2. Are the sites of initiation distributed randomly along the chains, in which case initiation is proportional to the mass of material, or are they distributed in such a fashion that each chain has the same number, i.e., initiation is proportional to the number of polymer molecules?

Preparations of all polymers may, of course, contain impurities, such as oxidation products produced during or after polymerization. The question that arises is whether it is ever possible to have a polymer pure enough that its decomposition is characteristic of the polymer alone. The answer is yes, because at some degree of purification the number of bonds of the polymer are numerous enough that their rate of breaking will outweigh those occurring at weak sites.

The mechanism of initiation seems established at the moment for only three polymers: poly(alpha-methylstyrene) (random), poly(methyl methacrylate) (end and random), and polystyrene (end).

In *Figure 1*, it is seen that the rate of volatilization increases with the size of the polymer molecule and fits closely the theoretical curve for random initiation and an average zip length of 1342. [28] The average zip length is the average number of monomer units depropagated from each radical formed via either pure initiation or intermolecular transfer. The major portion of the curves plotted in *Figure 1* represents a transition between the situation where the zip length is larger than the degree of polymerization, D.P., and that where it is smaller. Theoretically, the former situation leads to a rate proportional to the D.P. and the latter to a rate independent of D.P.

In *Figure 2*, the initial rates for some poly(methyl methacrylates) studied by Grassie and Melville [29] are plotted as a function of the square root of the number-average molecular weight. The curve represents theory

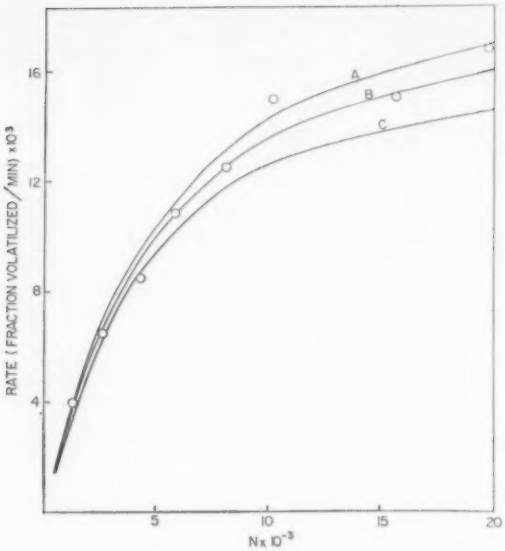

Figure 1. Initial rates of volatilization as a function of N (or 2 x D.P.) for poly (alpha - methylstyrene) fractions. Points are experimental; curves are theoretical [21]; average zip length: (A) 1476, (B) 1342, (C) 1208.

for end initiation, and it is seen that the experimental data follow it reasonably well. With end initiation, the zip length, Z, is proportional to the square root of the D.P.; not independent as for random initiation. Thus, the data for poly(methyl methacrylate) presented in *Figure 2* leads to $Z = Z_n N^{1/2}$ for the zip length Z_n which is a constant for the system having the value 58. These results apply only to the initial stage of pyrolysis. In most poly(methyl methacrylates) studied, the rate drops to negligible values at around 50% conversion, and the overall activation energy rises from 32 to 47 kcal/mole. Brockhaus and Jenckel [30], in their studies of this polymer, analyzed their data in terms of two component reactions; one is important at low conversion, the other important at high conversion. The latter reaction varies with molecular weight in the same manner as the data for poly (alpha-methylstyrene) shown in *Figure 1*. Their findings thus show, as they deduced [30], that about 50% of the material decomposes by random initiation and 50% by initiations proportional to the number of polymer molecules, which clearly suggests end initiation but does not completely remove the possibility that the initiating site is in the interior of the chains.

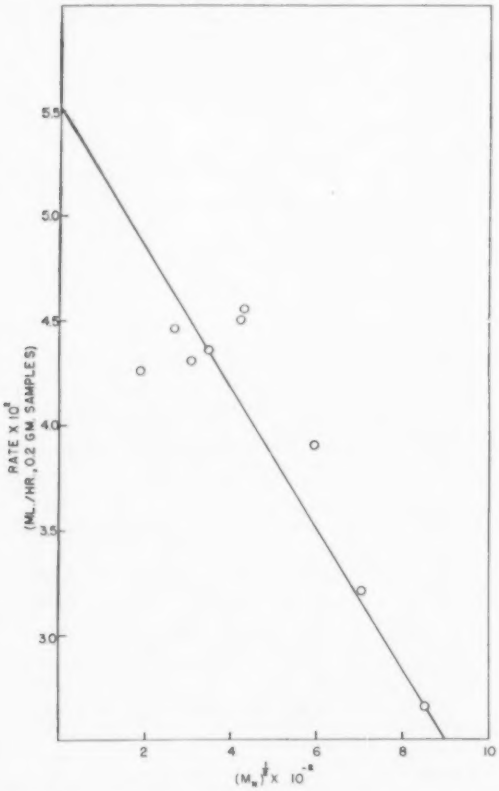

Figure 2. Initial rates of volatilization as a function of the number-average molecular weight for polymethylmethacrylate. Points are experimental [29]; curve is theoretical.

When polystyrene is pyrolyzed, the curve for the rate of volatilization-versus-conversion goes through a maximum which is at higher conversion than any yet given by mechanisms theoretically treated. However, end initiation mechanisms remain to be exploited. The rate of volatilization for polystyrene is comprised of a component of about 40% for pure monomer and another of about 60% for other products which are dimer to pentamer [31]. It has been shown [32] that the monomer rate parallels almost exactly the total rate of volatilization and hence goes through a maximum. Assuming initiation at the ends and estimating the number of ends during the pyrolysis from the experimental molecular weight-versus-conversion curve, the rate-versus-volatilization curve has been neatly fitted [33]. Thus, during the course of the reaction the evidence indicates end initiation. However, nothing is really known about the mechanism of initiation in the original polymer. What we do know is that once degradation starts, end initiation is occurring.

Polytetrafluoroethylene, a polymer whose mechanism of decomposition presents something of a dilemma, decomposes [34] at rates nearly linear with mass of polymer and yields very nearly 100% pure monomer. Numerous polymers of tetrafluoroethylene prepared in various ways with various catalysts, including fluorine gas, all have essentially the same rate of volatilization, suggesting random initiation [35]. With zip lengths [20, 21] of about 10^3, so-called first-order kinetics are obtained with both end and random initiation. The "order" of a polymer decomposition usually refers to the dependence of rate on the amount or mass of polymer being volatilized (decomposed). Therefore the term does not have its usually kinetic significance, which refers to the dependence of a rate on the number of molecules reacting. Some studies [36] of polytetrafluoroethylene decompositions suggest end initiation because of the observance of a partial zero-order dependence of rate

on mass. However, because large samples (~ 1 g) in an atmosphere of nitrogen were used it is possible that diffusion effects were responsible for the observation. Finally, a study [37] has shown that the rate for polytetrafluoroethylene decomposition is independent of molecular weights over a range from 5×10^6 to 10^7. In polymers where transfer is so unlikely and where a high monomer yield is obtained, one would intuitively assume that the zip length is at least 10^8. With $Z \sim 10^8$, a dependence on molecular size should be observed for random or end initiation provided a sufficient range of molecular weights are studied. *Figures 1 and 2* illustrate these possibilities. Therefore, the lack of dependence poses a dilemma, since it is believed that the D.P.'s studied [35, 37] ranged from 10^5 to 10^6.

Further work is needed to establish the mechanism of initiation for this polymer. However, the following possibilities apply to the situation: random initiation and zip lengths much shorter than 10^8, which are difficult to believe, or end initiation with zip lengths of at least 10^8. The latter case seems more reasonable since for end initiation the zip length is proportional to the square root of the D.P. If the latter case were true, the thermal decomposition of the polymer should be quite sensitive to photolytic initiation provided an appropriate wavelength of light were used. Mechanisms involving both end and random initiation may also conceivably give rates independent of molecular weight over a wide range. Experiments aimed at the resolution of this problem are now being initiated in our laboratory.

Since the decomposition of polytetrafluoroethylene is a chain reaction, inhibition is possible in theory [36, 38], and some experiments in this direction have been made, using different gases for the inhibition. However, every substance that gave evidence of reacting with depropagating radicals appeared to initiate radicals also. In these cases the behavior of the decomposition drastically changed and became similar to the behavior observed with linear polyethylenes, indicating a net random decomposition.

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Next Month—Energetics and Atomic Radiation of Polymers

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Edited by **Dr. Irvin Wolock**
U.S. Naval Research Laboratory

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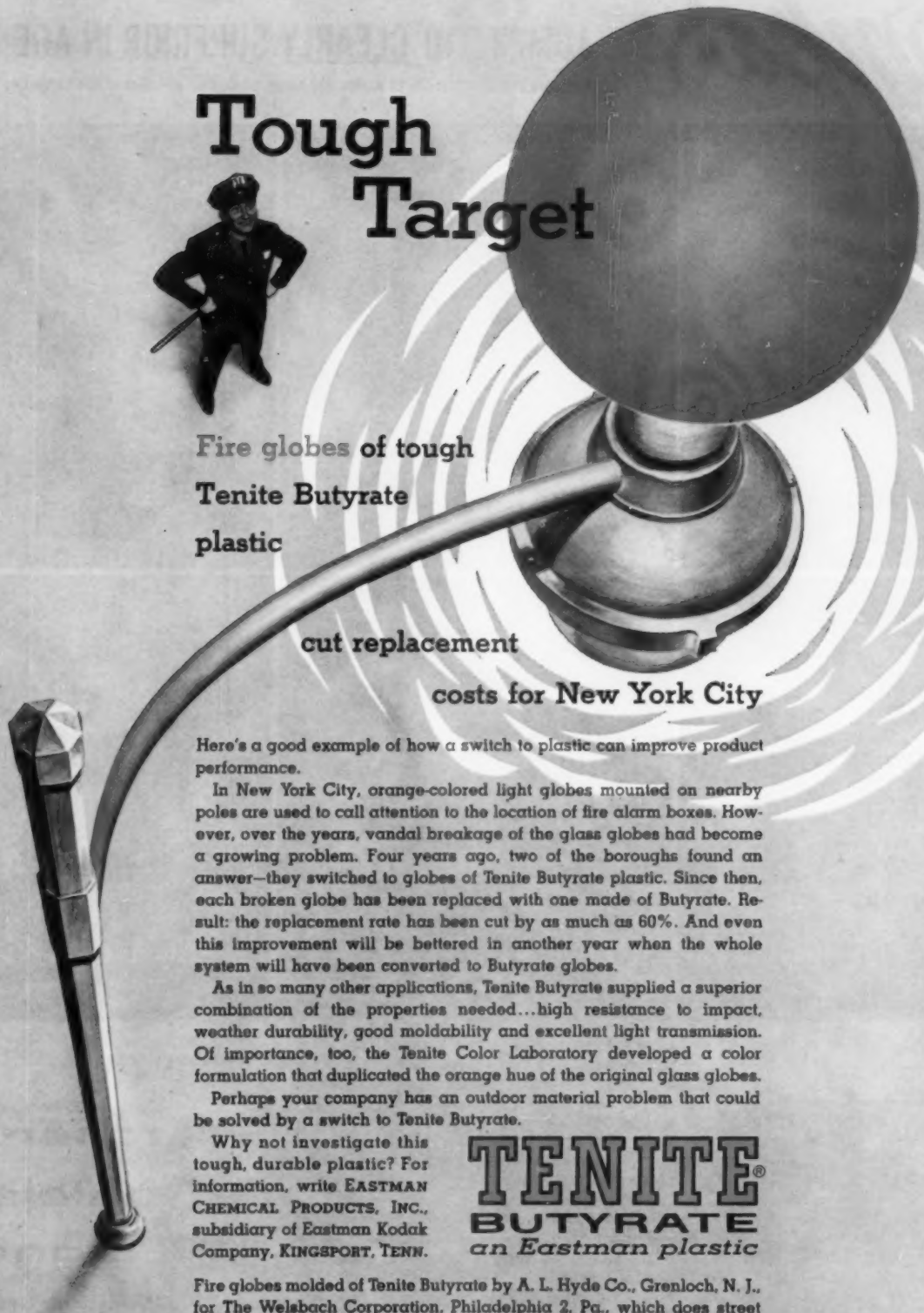
Tough Target



Fire globes of tough Tenite Butyrate plastic cut replacement costs for New York City

Here's a good example of how a switch to plastic can improve product performance.

In New York City, orange-colored light globes mounted on nearby poles are used to call attention to the location of fire alarm boxes. However, over the years, vandal breakage of the glass globes had become a growing problem. Four years ago, two of the boroughs found an answer—they switched to globes of Tenite Butyrate plastic. Since then, each broken globe has been replaced with one made of Butyrate. Result: the replacement rate has been cut by as much as 60%. And even this improvement will be bettered in another year when the whole system will have been converted to Butyrate globes.

As in so many other applications, Tenite Butyrate supplied a superior combination of the properties needed...high resistance to impact, weather durability, good moldability and excellent light transmission. Of importance, too, the Tenite Color Laboratory developed a color formulation that duplicated the orange hue of the original glass globes.

Perhaps your company has an outdoor material problem that could be solved by a switch to Tenite Butyrate.

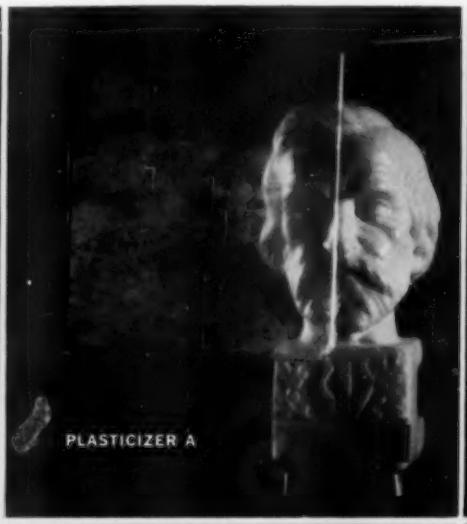
Why not investigate this tough, durable plastic? For information, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENN.

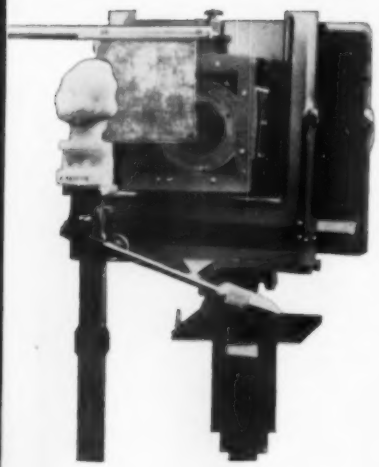
TENITE® BUTYRATE
an Eastman plastic

Fire globes molded of Tenite Butyrate by A. L. Hyde Co., Grenloch, N. J., for The Welsbach Corporation, Philadelphia 2, Pa., which does street lighting maintenance for the City of New York. Commenting on the considerable reduction in replacements since switching to Butyrate, Welsbach's New York City manager says, *"Butyrate's resistance to shock is so great that no replacement is necessary when the globes are pierced by BB shot or even small bullets. They resist damage from small stones, and even large rocks will only tear the Butyrate, leaving the globe in serviceable condition."*

Compare ADMEX 710 CLEARLY SUPERIOR IN AGE TEST

Compare the compatability of ADMEX 710 epoxy plasticizer with that of five competing products:





Here are unretouched photographs of vinyl test sheets* exactly as they appear after aging. Compare. Note the heavy, waxy plasticizer exudation on the vinyl sheets formulated with competitive epoxies. Then note the perfect clarity of the ADMEX 710 sheet. As you see, ADMEX 710 shows no sign of spewing after 12 months' aging. This proves marked superiority not found in most competitive products.

ADMEX 710 serves double-duty as plasticizer and stabilizer. It permits important economy in compounding all vinyls . . . provides outstanding heat and light stability, as well as resistance to migration and extraction in calendered, extruded, molded, and cast vinyl compounds.

For further information on this exudation test, and on ADMEX PLASTICIZERS, write, wire, or call your ADM representative today.

Archer-Daniels-Midland

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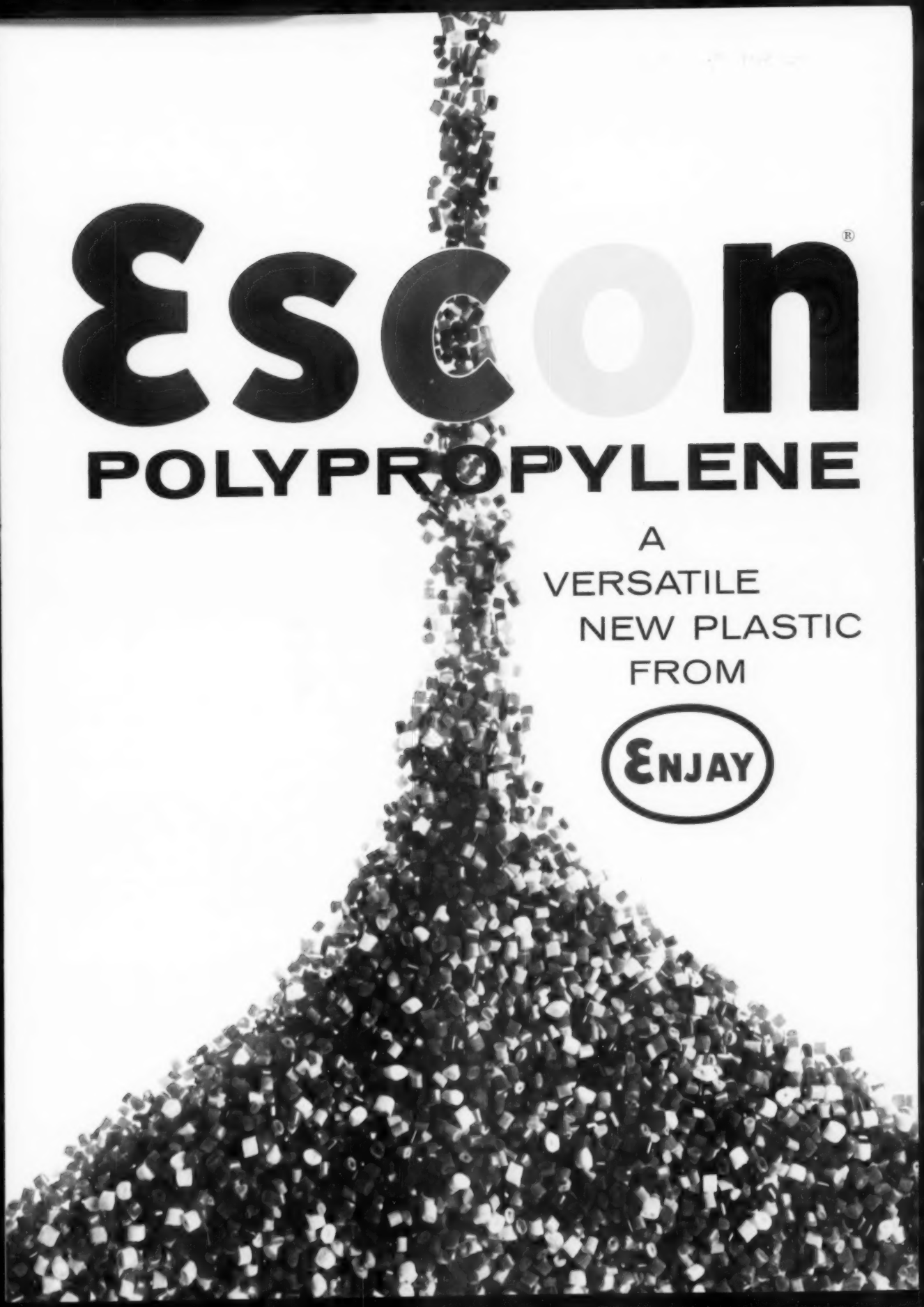
RESINS · PLASTICS
INDUSTRIAL CHEMICALS

700 Investors Building, Minneapolis 2, Minn.

*Compounded of 50 parts epoxy plasticizer to 100 parts polyvinyl chloride resin. (Not a recommendation for the use of epoxidized soybean oil, but a comparative test compound.) Stored in individual paper envelopes in the dark at room temperatures, some sheets showed pronounced exudation in as little as four months. ADMEX 710 sheets were clear after 12 months' aging. Similar comparative data were observed in north light window exposures between three and six months.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POLYPROPYLENE
A
VERSATILE
NEW PLASTIC
FROM
ENJAY

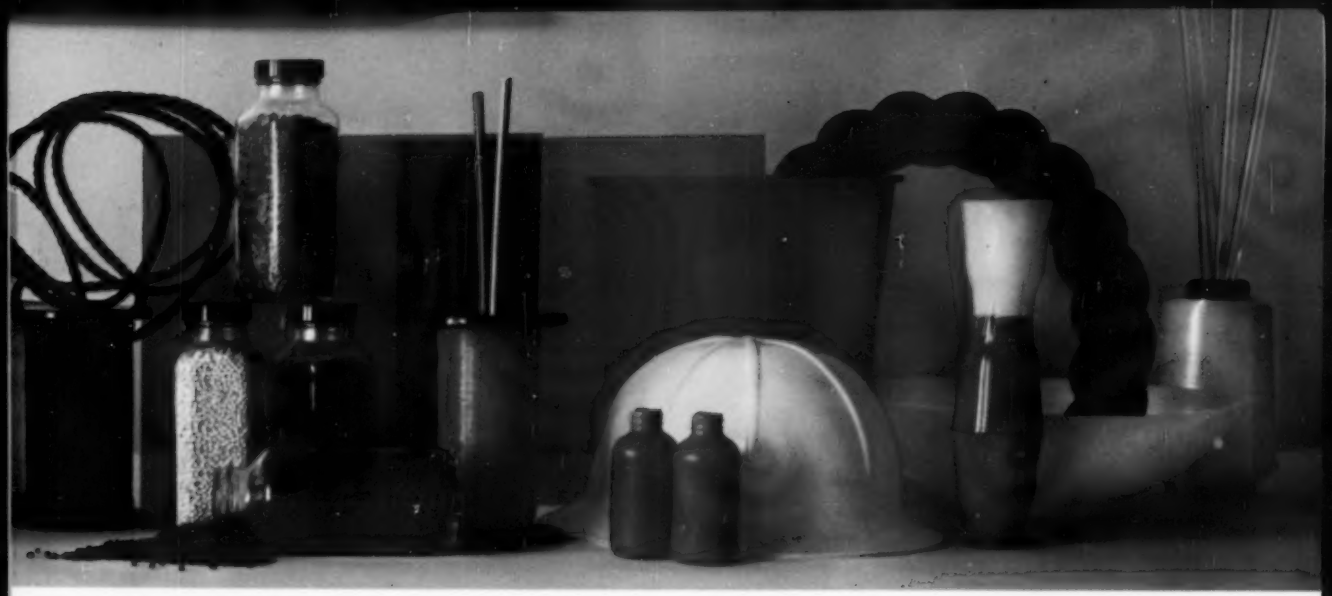
Specify Escon

ENJAY

This new thermoplastic resin is the world's lightest plastic. Yet it provides excellent strength and rigidity. It can be made in brilliant lasting colors with high surface gloss and hardness. Escon also offers outstanding resistance to chemicals and stress cracking. Versatile Escon can be processed in a wide variety of ways. For example, it can be injection molded;

FOR PACKAGING. Escon film can be produced by water bath or chill roll technique with extreme clarity and gloss. It offers greater heat resistance than any other polyolefin and can be sterilized by heat or chemical means. In addition, Escon offers excellent stiffness and toughness. Escon clear film can be color printed on either side — or both sides — for extra eye and buy appeal.

FOR MOLDING. Because of its light weight, Escon yields more pieces per pound. In injection molding, Escon's high strength plus its unique chemical and abrasion resistance makes it suitable for the manufacturing of many consumer products. Escon also allows accurate reproduction of fine and intricate designs with high surface lustre.

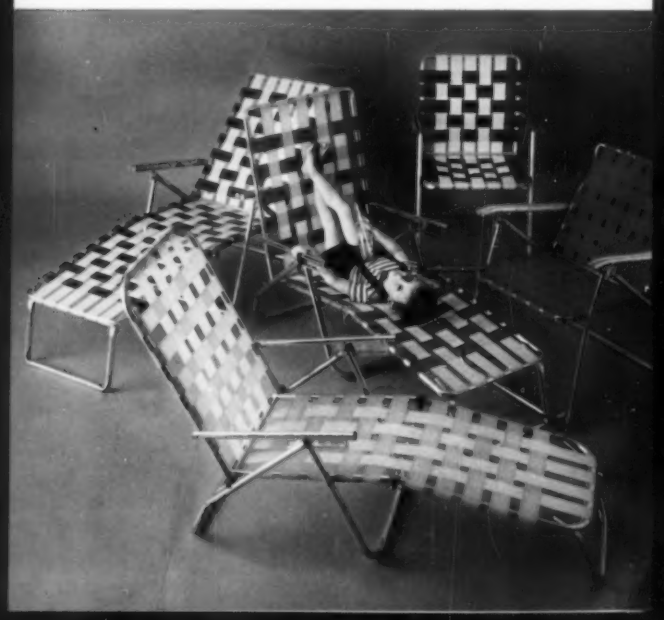


polypropylene for new beauty, utility and economy

extruded into film, sheet and shapes. It can also be drawn and thermoformed, heat sealed, machined and printed. Because of the rigid manufacturing standards of the Enjay Chemical Company, molders and designers are assured of high uniform quality whenever they specify Escon polypropylene. Versatile Escon can be tailor-made to meet a variety of product needs.

FOR EXTRUDING. Escon may be extruded in an almost unlimited range of thicknesses and forms. Its excellent physical and chemical properties make it an ideal plastic for such operations as thermoforming, punching, machining, die cutting and welding. Surface details are accurately reproduced too. And pigmentation, before or during extrusion, produces brightly colored sheet stock.

FOR FIBERS AND MONOFILAMENTS. Escon allows more yards of fiber per pound. Its high tensile strength, good knot strength and resilience, plus its immunity to attack by fungus, moths and marine organisms make it ideal for ropes and woven fabrics. Escon fibers show excellent wet strength, wet flexing durability, and abrasion resistance maintained to minus 70°F.



TYPICAL PROPERTIES OF

Escon POLYPROPYLENE

July, 1960

Various grades of Escon are offered to permit the processor to choose the grade best suited to his needs. Values for properties tabled at right will vary depending upon how the sample is formed and treated. Ask us for help on your specific requirements.

How Enjay helps you profit with Escon — Escon can help your product do a better job. To assure this, Enjay offers you complete technical assistance from one of the world's best staffed and equipped technical service laboratories. Here Enjay scientists can help you develop new products and improve existing ones through efficient use of Escon polypropylene.

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ENJAY

PLASTICS

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

PROPERTY	DATA	METHOD
GENERAL		
density, 73°F., g./cc.	0.902	ASTM D1505-57T
environmental stress cracking (100% Igepal CD-603)	none	Bell Labs.
burning rate	slow	ASTM D635
mold shrinkage, in./in.	0.015-0.030	
water absorption, %	<0.01	ASTM D570-57T
MECHANICAL		
yield strength, psi, 2"/min.	4700	ASTM D638-58T
yield elongation, %, 2"/min.	15	ASTM D638-58T
Impact strength, ft. lb./in.		ASTM D256-54T
Izod notched	1	
Izod unnotched	>16	
hardness		
Rockwell R	85	ASTM D785-51
Shore D	75	ASTM D676-55
elastic modulus, psi, 2"/min.	150,000	ASTM D638-58T
compressive yield stress, psi, 0.05"/min.	6,000	ASTM D695-54
stiffness in flexure, psi	180,000	ASTM D747-58T
Taber abrasion, mg. loss/1000 cycles (CS-17 wheel, 1000g. load)	28	
THERMAL		
melting point, °F.	335	polarizing microscope
vicat softening point (1 kg.), °F.	280	ASTM 1525-58T
deflection temperature		ASTM D648-56
°F. @ 264 psi fiber stress	150	
°F. @ 66 psi fiber stress	230	
coefficient of thermal conductivity		
cal./cm./cm.^{2}/sec./°C.	2.80×10^{-4}	
BTU/in./ft.^{2}/sec./°F.	1.13	
coefficient of linear thermal expansion in./in./°C.	0.00020	ASTM 696-44
specific heat @ 73°F., cal./g.	0.46	
ELECTRICAL		
volume resistivity, ohm-cm	1×10^{15}	ASTM D257-54T
dielectric strength, volts/mil		
short-time, 1/8" thickness	660	ASTM D149-55T
step-by-step, 1/8" thickness	650	
dielectric constant, 10^6 cycles	2.1	ASTM D150-54T
dissipation (power) factor, 10^6 cycles	0.00025	ASTM D150-54T

CHEMICAL RESISTANCE	
weak acids	excellent
strong acids	good (slow attack by oxidizing acids)
weak alkalies	excellent
strong alkalies	excellent
organic solvents	good below 175°F.

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Giguere, Rolland
Gillis, James C
Goudey, John F.
Greene, Robert H.
Grinstead, Robert L.
Hale, George M.
Hardie, John W.
Harman, A. John
Hinkhouse, W. D.
Houle, Rosarie J.
Jackson, Donald H.D.
Johnston Robert A.
Jonah, Wilford B.
Lafond, R. G.
La Fontaine, Leo
Laincesse, Benoit
Laincesse, Bruno
Lapierre, Edouard C.
Le Pointe, Paul
Larson, Hans R.
LaRue, Louis L.
Lawrence, Gordon H.
Le Febvre, Charles
Leroux, Roger
Letourneau, Gerard R.
Lewis, A. Beverley
Longtin, Oswald J.
Lukian, William
Lynes, William E.
Mac Donald, John L.
MacEachern ,Clinton W.
MacIntyre, Bruce K.
Mac Kenzie, Eric A.
Mac Laine, Ivan A.
Mac Leod, Lester C.
Malone, Maurice F.
Mann, John W.
Marmur, Ben
Mason, D. F.
May, Edward W.
McCabe, James Kevin
Mc Farland, John S.
McLean, Stanley R.
Meredith, Lloyd A.
Methe, Jean
Millard, John Warren
Miller, Hugh Laurence
Mineau, Marcel
Mizuhara, Shaw J.
Moreau, Eugene J.
Morris, Joseph R.
Morrison, M. E.
Muir, Edgar C. H.
Neal, John Arthur
Palmquist, David E.
Pangman, Peter M.
Planck, Robert V.
Potter, Alan B.
Powers, L. Jack
Pritchard, Joseph P.
Pyves, Edward L.
Quarles, James W.
Quesnel, Paul E.
Rehill, Donald M.
Rheaume, Paul
Rhodes, Brian W.
Roy, Louis
St. Eve, Daniel
Seguin, Andre
Shepardson, Wilfred B.
Shepherd, Robert F.
Sibalis, Jack
Simko, Michael
Speirs, Alex. Bain
Stellings, Don A.
Storey, James
Summerfield, Cyril
Suter, Ernest P.
Tripp, Robert A.
Trudel, Yves
Upton, F. B.
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Vasarhelyi, I. A.
Waldo, Stuart
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Smith, Roy S., Jr.
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Steele, Harry V.
Steiner, Robert H.
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Tullar, Dudley D.
Turrell, Merton R.
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Van Epps, Clarence F.
Venturelli, Vincent S.
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Williams, Robert F.
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Csabi, Menyhert
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Eells, Donald E.
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Fisler, Royal E.
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Gerber, Albert J.
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Grossman, Harold
Grossman, Jack
Hagemeyer, Charles F.
Hall, Ford R.
Hanrahan, Paul B.
Hawes, Frederick Lee
Hawes, Richard S.
Heisel, Val B.
Hessic, George H.
Herzog, Armin M.
Igeler, Harold J.
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Kacalieff, Christ D.
Kalde, Harold I.
Karasek, Robert A.
Kerr, R. W.
Klorer, Robert W.
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Weber, Orville O.
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Lilly, James H.
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Meath, William A.
Metz, Peter J.
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Moore, Trevor W.
Morris, John B.
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Nettles, Charles M.
Perry, Eli
Pinkston, James T.
Raudsep, John G.
Richarson, Dean E.
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Rose, Elwood A.
Rosen, Martin
Samuels, Julian J.
Sanders, Harold W.
Sandow, Kiyoshi
Schramm, William
Schutze, Henry G.
Schwar, James P.
Scott, Harry D.
Shannon, Edward D.
Shay, Phil
Sherman, Norman G.
Smith, Arthur A.
Smith, William F.
Snakenberg, Randolph F.
Spradling, James B.
Teves, Fred W.
Theobald, Robert W.
Thomas, Sebern A.
Tuxson, R. O.
Uffner, Melville W.
Van Erp, George D.
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Walker, Robert L.
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Bangs, Howard T.
Barhoff, Fred W.
Barrowman, A. Victor
Barrowman, Arthur H.
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Benander, Clifford N.
Bennett, Noel B.
Binch, David
Blau, Benjamin
Borden, Herbert M.
Bottleman, Raymond R.
Bottomley, Anthony
Boyden, Howard C.
Bray, Calvin S.
Brinton, Garrison W.
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Brown, Bertram M.
Brown, Robert M.
Bruce, Richard H.
Buzzee, Robert D.
Callahan, Edward W.
Card, Francis E.
Carver, Irving
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Chrones, Anthony
Chrones, Charles D.
Clancy, Joseph F.
Clancy, George F.
Coburn, Clarence J.
Conroy, William R.
Cowan, Clifton J.
Cuddy, Samuel
Cuddy, Thomas
Cushing, James J.
Dahl, Nils J.
Davis, Benjamin H.
Davis, Lawrence N.
Del Ponco, Andrew
Deveau, Dennis F.
Dmytryshyn, Michael
Doob, Jr., Hugo
Doyle, Ernest W.
Duzza, Stanley C.
Dyer, William J.H.
Edenbaum, Jesse
Eliason, Carl E.
Ellis, Carlton M.
Esposito, Frank
Evans, Lloyd G.
Falcon, John E.
Ferris, James M.
Fenti, Vincent
Finnegan, David A.
Fitzpatrick, Edwin N.
Forsberg, George E.
Freelander, I. Robert
Gordon, Ira B.
Grad, Peter P.
Greene, Philip C.
Greene, Samuel N.
Haas, Erolle J.
Hebert, Maurice G.
Hobaica, Edward C.
Holt, John E.
Hoyer, Robert
Johnson, J. Robert
Jones, Philip B.
Kalarian, Z. Stephen
Kaplan, Theodore
Kaster, Herbert H.
Klaburner, David P.
Korman, Melvin
Krajewski, Alexander J.
LaBrie, Armand R.
Ladd, Roderick M.
Lange, Jr., Robert R.
Lee, Thomas A.
Lentz, James W.
Lindstrom, Althen C.
Lohman, Sydney W.
Lowe, Charles
Maher, Walter A.
Malo, Urbain J.
Marsland, Robert A.
Martin, Cecil
Martin, Reynol H.
McBride, Jack W.
McCool, Edward T.
McCreery, Albert J.
Menese, Anthony W.
Meyers, Howard J.
Miner, Frederic I.
Mitchell, Peter A.
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Morrison, Donne I.
Mouradjian, Souren
Murphy, Jr., Frederick V.
Napolitano, Michael
Nathanson, Abraham
Natorski, Theodore J.
Nelson, Alden W.
Newman, Irving I.
Niquette, Earl G.
O'Connor, Hubert P.
Pearson, Walter A.
Peck, Robert F.
Peterson, Russell I.
Polson, Allen E.
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Pressman, William M.
Recchia, Orlando R.
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Riggs, Horace S.
Rizzo, Bart
Robbins, Louis
Robert, Albert F.
Robinson, Lewis H.
Rose, Edward I.
Rose, Norman K.
Roveda, Harold C.
Roy, Hubert F.
Royden, Markus D.
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St. Lawrence, Albert F.
Sahagian, Sahag
Sandahl, Russel A.
Scanlon, Edward C.
Sharland, Richard H.
Silva, Victor C.
Silver, Michael S.
Slipp, Roy M.
Sloane, John R.
Smith, Allen E.
Smith, Fred M.
Sofro, Louis J.
Spadetti, Armando
Steaberg, John B.
Surdut, Albert M.
Swanson, Eskil P.
Swett, James B.
Symons, Ralph B.
Tamosauskas, Albert E.
Tanner, Glenn A.
Terpak, Anthony
Thomas, Clayton H.
Tourigny, Raymond J.
Tullman, Arthur S.
Vandenkerckhoven, William
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Blue, Frank C.
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Coogle, Kenneth L.
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Brown, Ralph
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Buck, Milton
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Conrad, Julius G.
Cooper, Scott A.
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Fine, Frederick R.
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Hamilton, Donald A.
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Hanson, Milo W.
Hanson, Victor
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Hanks, Marshall W.
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Harris, Ray H.
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Hessburg, Jr., Lawrence J.
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Hirschhorn, Gerard W.
Hultgren, Orville A.
Hultstrand, Winston R.
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Isleifson, Robert E.
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Johnson, Lennart I.
Johnson, Leonard S.
Johnson, Marvin G.
Johnson, Ray D.
Juba, Bernard T.
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Lynch, John E.
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DET	- Detroit
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MIL	- Milwaukee
MONT	- Monterrey (Mexico)
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NY	- New York
NS	- Non Section
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PH	- Philadelphia
PV	- Pioneer Valley
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QUE	- Quebec
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Union Carbide Plastics Co., 30 E. 42nd St. New York, N. Y.

YOUNG, ERNEST H. SlsRepr CHI
Koppers Co., Inc., Plastics, 122 S. Michigan Ave., Chicago 3, Ill.

YOUNG, FOSTER J. MgrProcEngr AK
Goodyear Tire & Rubber Co., Research, 1144 E. Market St. 16, Ohio mail: 2143 17th St., Cuyahoga Falls, Ohio

YOUNG, H. CLIFTON GenlMgr PH
Heisler Corp., P. O. Box 1648, Wilmington 99, Del. mail; 2006 Eden Rd., Wilmington 3, Del.

YOUNG, J. ARTHUR FacilitiesEngr SNE
Owens Corning Fiberglas Corp., Ashton, R. I.

YOUNG, JAMES A. Owner GG
Young Development Co., 1550 Willow Oaks Dr., San Jose 25, Calif.

YOUNG, JESSE S. Pres NY
Jesse S. Young Co., Inc., 11 W. 42nd St., New York 36, N. Y.

YOUNG, JOHN D. MgrAutoDev DET
E. I. du Pont de Nemours Plastics Co., Inc., Polychemicals, 13119 W. 7th Mile Rd., Detroit 35, Mich.

YOUNG, JOHN L. CHI
Monsanto Chemical Co., 520 North Michigan Ave., McGraw-Hill Bldg., Chicago 11, Ill.

YOUNG J. V. Engr NT
Chance Vought Aircraft, Dallas, Texas mail: RT. 2, Lewisville, Texas

YOUNG, Jr., JOSEPH V. MatrlDevEngr NT
Chance Vought Inc., Astronautics, Box 5907, Dallas, Tex. mail; R. R. 2, Lewisville, Tex.

YOUNG, LEWIS J. Chemist DET
The Dow Chemical Co., Midland, Mich. mail; 3200 Lakeside Dr., Sanford Mich.

YOUNG, PAUL W. Pres-Treas TOL
Napco Plastics Inc., 500 Glenwood, Napoleon, Ohio

YOUNG, SHERWOOD L. WNE
Vice-Pres,ProdEngr&Dev, American-Standard, C. F. Church Div., N. Main St., Monson, Mass.

YOUNG, WILLIAM G. Chemist NY
The Mearl Corp., 1057 Lower S. St., Peekskill, N. Y.

YOUNG, WILLIAM H. AsstGenlMgr ENR
Morningstar Corp., 156 6th St., Cambridge 42, Mass. mail: 16 Old Farm Rd., Wayland, Mass.

YOUNG, WILLIAM H., Jr. PlantMgr B-W
Pharmaplastics Inc., 205 S. Smallwood, Baltimore 23, Md.

YOUNG, WILLIAM W. Mtrl&ProcEngr BW
Westinghouse Electric Corp., Air Arm Div. Friendship Int'l Airport, Baltimore 3, Md. mail: 4102 8th St., Baltimore 25, Md.

YOZO, FUKUDA DirVP OSA
Kobe Electric Machinery Co., Ltd., Plastic Plant, 15, 5-Chome, Urae kita, Oyodo-ku, Osaka, Japan

YURECKA, MILTON J. BI
ForemanPolyethyleneProcPlnt, Endicott Johnson Corp., Plastics Div., Johnson City, N. Y. mail: Plastics Div., Polyethylene Processing Plant, Johnson City , N. Y.

YUSTER, CHARLES TechnRepr NWK
The Mearl Corp., 41 E. 42nd St., New York City 17, N. Y. mail: 60 Woodland Ave., Great Kills 8, S. I. N. Y.

Z

ZABEL, HERMAN W. Exec-VP NY
Roger Williams, Inc., P.O. Box 426, Princeton, N. J.

ZACKS, EDWARD A. Pres NWP
Eirie Plastics Co., Erie Iron & Supply Corp., P.O. Box 1068, Erie, Pa.

ZADOR, GEORGE J. Mgr ONT
H. Muchlstein Co., Canada Ltd., 2 Carlton St., Toronto, Ontario, Canada

ZAGAR, WALTER T. ResChmst NWK
W. R. Grace & Co., Polymer Chemicals 225 Alwood Rd., Clifton, N. J.

ZAK, MURRAY D. PltMgr NY
Almor Plastics Corp., 1125 Close Ave. Bronx 72, N. Y.

ZAMARRA, PAUL A. Proprietor NWK
Plastic Mold Engr. Co., 106 Naylor Ave., Livingston, N. J.

ZAPPA, JOSEPH F. MechEngr NWK
Zappa Tool Corp., R. F. D. 2 Box 158, Bound Brook, N. J.

ZAREBSKI, MICHAEL A. ChemEng ONT
Reichhold Chemicals (Canada) Ltd., 1919 Wilson Ave., Toronto 15, Ontario, Canada

ZARLINSKI, EUGENE A. Secy CLEV
State Plastics, Inc., 22240 Lakeland Blvd., Euclid 23, Ohio

ZASKE, OSCAR C. TechResp SC
Durez Plastics Div., Hooker Chemical Corp., 3325 Wilshire Blvd., Los Angeles 5, Calif.
mail: 1227 Third St., Manhattan Beach, Calif.

ZAVASNIK, FRED J. ProjEngr B-T
Phillips Petroleum Co., R. & D. Div., 115 N. Johnstone, Bartlesville, Okla. mail: 1621 S. E. Melmart Dr., Bartlesville, Okla.

ZAVERTNIK, MARSHALL G. ChfEngr SL
Killark Electric Mfg. Co., 3940 Easton, St. Louis 13, Mo. mail: 3919 Russell, St. Louis 10, Mo.

ZAVIST, A. F. WNE
Supv-ChemEngrg&InsulationDev, General Electric Co., Turbine Div., Bldg. 7, Rm. 311, Schenectady 9, N. Y.

ZAWADZKI, THOMAS VP NY
Cary Chemicals Inc., Box 1128, New Brunswick, N. J.

ZAWODNI, JAMES T. Exec-VP DET
Acme Abrasive Co., 24200 Marmon, Center Line, Mich.

ZAYNE, J. EDWARD SupvrDev&EvalLab ENE
Deecy Products Co., 120 Potter St., Cambridge, Mass.

ZAZZARA, PATRICK B. GenMgr NWK
Jersey Plastic & Die Casting, 149-155 Shaw Ave., Irvington 11, N. J.

ZDAN-ZANIEWSKI, LUBOMIR J. PV
ExtrusionSupt, Commonwealth Plastics Corp., 68 Falulah Rd., Fitchburg, Mass. mail: 58 Maple Ave., No. Andover, Mass.

ZEEK, GERALD R. VPofMfg SNE
Tupper Co., Branch River Lab., Woonsocket, R. I.

ZEEKAF, J. G.M.E.H. Mgr NS
Meldon N. V., D65B, Bergen 1, Holland

ZEELO, JERRY VP CLEV
Plastics Mold & Die Co., 18526 Syracuse Ave., Cleveland 10, Ohio

ZEELO, THOMAS Mgr&Owner CLEV
Plastics Mold & Die Co., 18526 Syracuse Ave., Cleveland 10, Ohio

ZEGOTA, WALTER E. PlstcsResChmst DET
American Metal Products Co., 5959 Lindale, Detroit, Mich. mail: 27511 Sylvan Dr., Center Line, Mich.

ZEIGEN, VICTOR D. PlasticsEngr NS
Kalusia Importing Co., Kico, Apartado Aereo 295, Barranquilla, Colombia, S. A.

ZEIGER, HENRY B. Owner NY
Technical Product Co., 369 Lexington Ave., New York 17, N. Y.

ZEINER, EMMETT J. Partner SC
Plasti-mold Tool & Die, 944 W. Hyde Park Blvd., Inglewood, Calif.

ZEKAN, WILLIAM C. Exec-VP AK
A. Schulman, Inc., 790 E. Tallmadge Ave., Akron 9, Ohio

ZELLAR, EDWARD H. PlasticsSls CHI
E. I. duPont de Nemours & Co., Polychemicals Dept., 7250 N. Cicero Ave., Chicago 46, Ill. mail: 7022 N. Oleander Ave., Chicago 31, Ill.

ZELLEY, FENIMORE B. ProjEngr NWK
Curtiss Wright Corp., Propeller, Caldwell, N. J. mail: 41 Norman Rd., Upper Montclair, N. J.

ZELMAN, IRWIN M. TechSlsMgr SC
American Reinforced Plastics Co., 851 E. 60th St., Los Angeles 1, Calif. mail: 1415 Crestview Ct., Los Angeles 24, Calif.

ZELNICK, DAVID R. Pres RO
Atlas VAC-Machine, 1732 Hudson Ave., Rochester 17, N. Y. mail: 284 Russell Ave., Rochester 22, N. Y.

ZEMIANEK, JOSEPH P. SlsEngr KC
Reed-Prentice Div., Package Machinery Co., 330 Chestnut St., E. Longmeadow, Mass. mail: 406 W. 34th St., Kansas City 11, Mo.

ZEPEDA, EDMUND R. Mgr MONT
Auto Accesorios Ebexco, S. A., Tapia 550, Oriente Apartado Postal 1145, Monterrey, N. L. Mexico

ZERLIN, RICHARD M. ProjEngr NY
Seatectro Corp., 139 Hoyt Ave., Mamaroneck, N. Y. mail: 504 Fourth St., Mamaroneck, N.Y.

ZEVIN, ARTHUR H. AsstoVP NY
Ideal Plastics Div., Ideal Toy Corp., 184-10 Jamaica Ave., Hollis 23, N. Y. mail: 36-19 Browne St., Flushing 54, N. Y.

ZICCARELLI, JOHN J. SlsMgr CT
National Cleveland Corp., Plastics & Chemical Div., 1984 State St. Ext., Bridgeport 3, Conn. mail: 47 Forest Dr., Jericho, Long Island, N. Y.

ZIEGFELD, CARL J. DistMgr NWK
The Hydraulic Press Mfg. Co., 352 Cedar Lane, Teaneck, N. J. mail: P. O. Box 25, Teaneck, N. J.

ZIEMSKI, HENRY J. FrmnofInjectMldgDept NWK
Hommer Tool & Mfg. Co., 45-49 McWhorter St., Newark, N. J. mail: 40 Elm St., N. Arlington, N. J.

ZIMAND, GERALD P. ChfChmst NY
Rudd Plastic Fabric Corp., 620 62nd St., Brooklyn, N. Y., mail: 101 Joseph St., New Hyde Park, L. I., N. Y.

ZIMMERMAN, ABE PltSupt NWK
Lapin Products, Inc., 401 Park Ave., Rutherford, N. J.

ZIMMERMAN, ALAN K. Salesmen NY
Monsanto Chemical Co., Plastics, 445 Park Ave., New York, N. Y. mail: 34 Lincoln Ave., Port Chester, N. Y.

ZIMMERMAN, ALFRED B. CHI
ApplicationsDevEngr, U. S. Industrial Chemicals Co., Polymer Service Lab., Tuscola, Ill.

ZIMMERMAN, CARL Chmst NY
Metric Chemical Co., 22nd St., New York, N. Y., mail: 67-11 Yellowstone Blvd., Forest Hills 75, N. Y.

ZIMMERMAN, CHARLES C. Pres SC
West Coast Plastics Distributors, Inc., 9014 Lindblade St., Culver City, Calif. mail: 2442 Ronda Vista Dr., Los Angeles 27, Calif.

ZIMMERMAN, HARRY M. GenMgr SEO
Seiberling Rubber Co., Plastics Div., Newcomerstown, Ohio

ZIMMERMAN, ROBERT O. VP-Purchasing CO
The Plastex Co., A Div. The Zimmerman Co., 3232 Cleveland Ave., Columbus 24, Ohio

ZIMMERMAN, SAMUEL GenMgr ARIZ
Merit Creations, Inc., 324 Northrop Ave., Mamaroneck, N. Y.

ZIMMERMAN, SANFORD S. Pres NY
Zimmerman Machinery Co., Inc., 736 Canal St., Stamford, Conn. mail: P. O. Box 1402, Stamford, Conn.

ZIMTBAUM, SAMUEL D. SouthwestSlsMgr NY
Ideal Toy Corp., 184-10 Jamaica Ave., Hollis 23, N. Y. mail: 800 W. Wagon Wheel Dr., Phoenix, Ariz.

ZINBARG, BENSON E. Engr NY
Riverside Plastics Corp., 220 Miller Rd., Hicksville, N. Y.

ZINGSHEIM, ARTHUR J., Jr. MIL
ChemBdPres, Northland Plastics, Inc., P.O. Box 73, Sheboygan, Wis.

ZINK, NORBERT G. RO
FormanOfExperimentalMoldDept, Eastman Kodak Co., A. & O. Div., 343 State St., Rochester 14, N. Y. mail: 635 Holt Rd., Webster, N. Y.

ZIPKIN, SAMUEL Treas&SlsMgr WNE
Advance Mold & Mfg., Inc., 79 George St., E. Hartford, Conn.

ZIZZI, ROBERT F. SrDesigner BI
IBM, Owego Federal Systems Div., Owego, N.Y.

ZOBACK, HARRY A. SlsMgr PH
Berton Plastics, Inc., P.O. Box 17, Hatboro, Pa. mail: 291 Poplar Rd., Warminster, Pa.

ZOELLER, F. FRANKLIN CarbonBlackSls NY
Godfrey L. Cabot, 46 Bayard St., New Brunswick, N. J. mail: 5 Heather Lane, Levittown, Pa.

ZOGBI, ELIAS Z. ProdSupt MONT
Inyectora de Plasticos y Metales, S. A., Apartado Postal 674-Monterrey, N. L., Mexico

ZOLA, JOHN C. Dir SC
John C. Zola Labs., 409 So. Raymond Ave., Alhambra, Calif.

ZOLG, FRED U. SrResEngr MV
Cincinnati Milling Machine Co., Cimastra Div., 4701 Marburg Ave., Cincinnati 9, Ohio mail: 5075 Hagewa Dr., Cincinnati 42, Ohio

ZOLMAN, GEORGE R. Techn TOL
Libbey-Owens-Ford Glass Co., Research, 1701 E. Broadway, Toledo 5, Ohio

ZOMLEFER, JACK Pres PV
Solar Chemical Corp., 29 Fuller St., Leominster, Mass.

ZOMLEFER, SIDNEY SlsMgr PV
Solar Chemical Corp., 29 Fuller St., Leominster, Mass.

ZRADA, WALTER T. ExtrusionFrmn NWK
Keystone Plastics, 280 Badger Ave., Newark, N. J. mail: 33 Maple St., Edison Twsp., Nixon, N. J.

ZUBER, HAROLD E. GenMgr&Treas NWK
14 Beachview Dr., Lake Tamarack, Hardyston township, Sussex, N. J.

ZUBER, LEOPOLDO S. ChemEngr NS
Bakelite De Mexico S. A. 534 M. Escobedo, Mexico DF5, Mexico

ZUBRIN, DAVID Pres DET
Dale Plastics Corp., 5730 12th St., Detroit 8, Mich., mail: 24650 Radcliff, Oak Park 37, Mich.

ZUKOR, LEE J. EngrgEditor NY
Plastics Technology, 630 3rd Ave., New York 17, N. Y.

ZULKOWSKI, THEODORE J. MfgEngr NWK
IBM Corp., South Rd., Poughkeepsie, N. Y.

ZUMSTEIN, FRED R. Sls&ServEngr DET
Fellow Gear Shaper Co., P.O. Box 59, Detroit 20, Mich.

ZURAWEL, FRED A. TlRmFrmn SNE
New England Mold Corp., 2 Component Park, W. Bridgewater, Mass.

ZURKOFF, BERNARD TechSvcsEngr NWK
Enjay Labs., Plastics, P. O. Box 45, Linden, N. J. mail: 323 Summit Rd., Elizabeth, N. J.

ZURLINDEN, PAUL R. VP CLEV
Zenith Plastics Co., 3901 Superior Ave., Cleveland 14, Ohio

ZWIEBEL, NORMAN Pres NY
Plastic Enterprises, 124-14 22nd Ave., College Point 56, N. Y.

ZYSKOWSKI, ANTHONY E. Proprietor NWK
Konstan Plastics Co., 79 Paris St., Newark 5, N. J.

ZYSSET, EDGAR H. ExecutPres CHI
Battenfeld Corp. of America, 959 W. Grace St., Chicago 13, Ill.

U.S.I. POLYETHYLENE NEWS

A series of advertisements for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

AUGUST, 1960 — U. S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation — 99 Park Ave., N. Y. 16, N. Y.

Packaging Notes

Polyethylene handles for multi-trip refillable milk bottles as well as one-trip carriers for multi-unit packs of cans, bottles or jars, are now on the market.

Milk bottle handle

The milk bottle handles make half-gallon and gallon bottles easier and safer to carry and use.

The molded polyethylene multi-unit carriers, which can be used for beer cans, soft drink bottles and various grocery and household products, have a number of advantages over conventional carriers. Those cited for beer cans, for example: savings of 1 cent per six-pack; high-speed application of carriers—up to 1200 cans per minute; faster cooling when refrigerated; instantaneous product identification; quick stacking; containers easily removed; carrier unaffected by moisture; carrier easily discarded.

Multi-unit one-trip carrier

Polyethylene drum liners on a roll—heat-sealed at intervals and perforated just above the seal—have increased speed of lining corrugated cartons and drums threefold for one manufacturer. In the past, static electricity made the mouths of individual bags difficult to open; now, the tearing off action opens liners automatically. Photo shows workman pulling liner over mandril with one hand, while tearing it off roll overhead with the other. He'll simply flip both into drum, "cuff" the liner and remove the mandril.

Photo courtesy Bemis Bro. Bag Co.

Polyethylene bags in roll form have recently been introduced which will provide housewives with convenient containers for storing foods and other household items.

The prefabricated bags are packaged 25 to a roll in cartons similar to those used for waxed paper.

U.S.I. Introduces New PETROTHENE® Resin for Cast Film Extrusion

Produces "Soft Feel" Film of Exceptional Clarity and Gloss, High Stiffness

U.S.I. has developed a new 0.933 density polyethylene resin designed for cast film extrusion applications. The new resin – PETROTHENE 218 – has excellent processing characteristics and produces cast film with properties particularly suited to overwrapping soft goods, bakery products or paper.

Cast polyethylene film is an ideal packaging material for a virtually limitless number of consumer products.

Ultra-clarity is a key characteristic of cast film made from PETROTHENE 218. In transmittance and gloss, it equals or surpasses any other polyethylene film in the field. Haze is very low. Moreover, the film is easy to handle on overwrap equipment because of its high stiffness and good heat sealing properties.

For bakery goods, film made from PETROTHENE 218 is ideal. Its "soft feel" imparts a feeling of warmth and freshness, while its natural moisture barrier keeps products fresh longer. Clothing, too, takes on a soft-to-the-touch appearance not possible with "hard finish" overwrap materials.

Easy To Process

The new resin has a density of 0.933 and a melt index of 3.0. Its melt flow and hot-melt extensibility characteristics are excellent, permitting high haul-off rate (>200 ft/min) and relatively thin-gauge films (0.5 mil).

Extrusion stock temperatures of 450° to 550°F and casting roll temperatures of 80° to 170°F have been successfully used. Normally, of course, the highest stock and casting roll temperatures possible under given operating conditions will result in best-quality film.

Printability of films cast from PETROTHENE 218 is excellent. Film has been treated for printability in line with the extrusion process at rates of over 150 ft/min. With a moderate treat level, excellent ink adhesion has been obtained.

The resin is available in three formulations with varying slip levels: unmodified PETROTHENE 218, no slip; 218-26, medium-low slip; 218-27, medium slip.

Polyethylene-Lined Pails Now Used For Shipping Chemicals

Seamless blown-in-one-piece polyethylene liners for steel pails have been developed as another advance in solving the problem of safe and economical packaging of corrosive liquids. This container is expected to find wide application in packaging and shipping products such as acids and alkalies, food concentrates, photographic chemicals, electrochemicals and insecticides.

One-piece polyethylene liner insert permits use of steel pails for shipment of corrosive chemicals. (Photo courtesy Jones & Laughlin Steel Corp.)

The liner is blow-molded of polyethylene in the same manner as a "squeeze bottle," and is then attached to the cover of the outer steel container at the pouring opening, before it is inserted in the container. Its one-piece construction is said to insure against leakage and product contamination.

New Help in Selecting Best Polyethylene Film to Use

A revised edition of the 4-page brochure, *Which Polyethylene Film Should I Use*, incorporating the new Commercial Standard CS227-59 for Polyethylene Film has just been issued by U.S.I. The brochure lists film requirements and resin types suggested for 33 classes of packaged goods, in the terminology used in the new Commercial Standard.

The new U.S.I. brochure provides extruders with an easy-to-use reference to the principal applications of polyethylene film as defined in the new Standard and suggests applicable PETROTHENE resins for these uses. Copies may be obtained by writing to Technical Literature Department, U.S. Industrial Chemicals Co., 99 Park Ave., New York 16, New York.

Cast 1.25 mil polyethylene film from regular production run using PETROTHENE 218 resin.

DO YOUR CUSTOMERS . . . AND YOURSELF . . . A SERVICE SHOW THEM THIS CLARITY AND GLOSS

It's cast polyethylene film made from U.S.I.'s new PETROTHENE® 218 resin – ideal for overwrap for bakery products, soft goods, paper products; ideal to process.

With U.S.I.'s new resin for cast film extrusion you get clarity, gloss, and freedom from haze that no other overwrap can surpass.

On the shelf, products overwrapped with cast film from PETROTHENE 218 have a sales-spurring sparkle. And when a shopper reaches, she's completely sold – the film's "soft feel" imparts a feeling of warmth and freshness to bakery products . . . a feeling of softness to clothing that "hard finish" overwraps can't suggest.

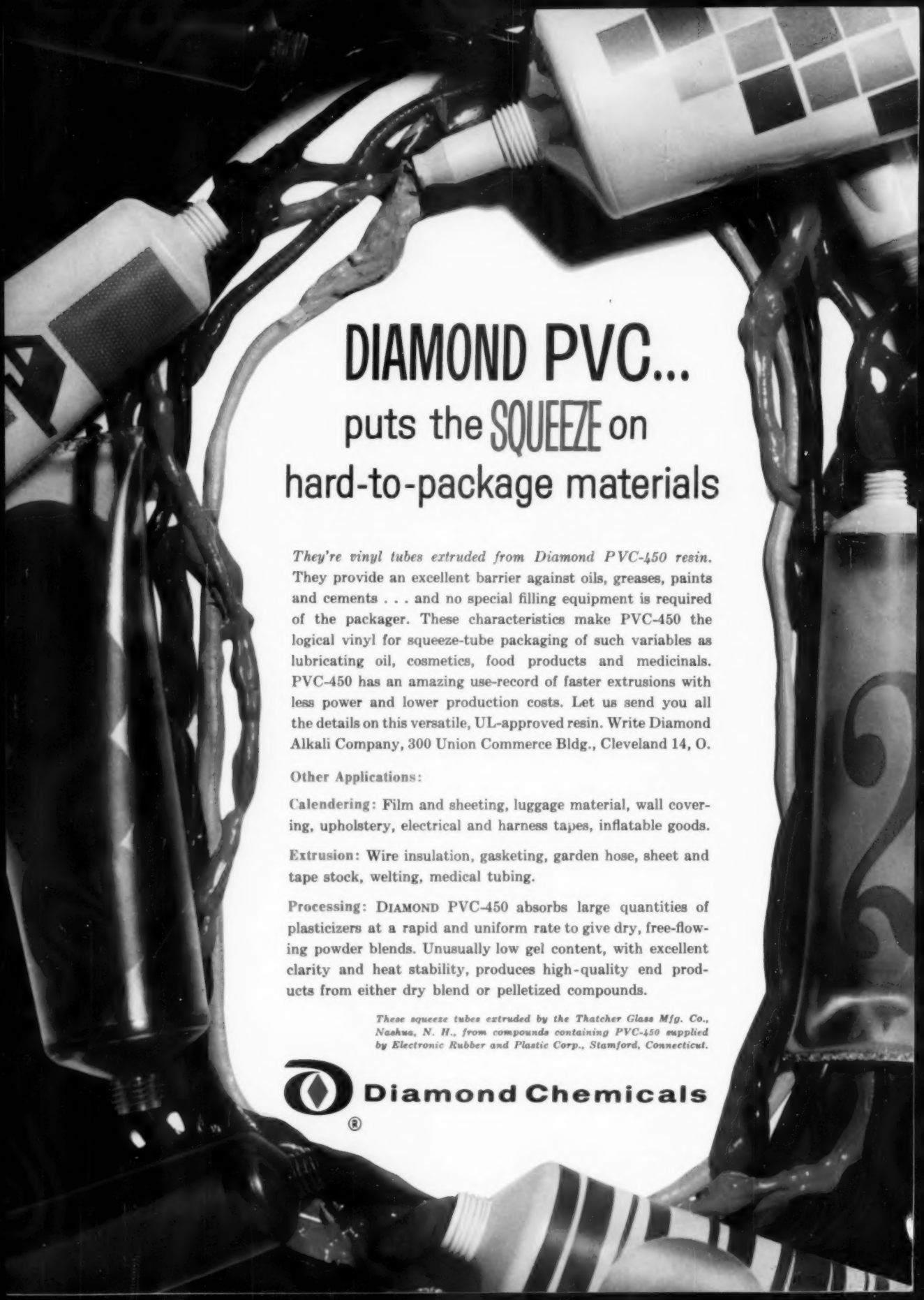
For your customers, this superior film means more sales, fewer returns, greater economy. Strong and resistant to moisture and grease, cast polyethylene film also has high stiffness; this makes it easy to handle on overwrap equipment designed or modified to handle polyethylene film. It's easy to print, easy to heat seal. And cast polyethylene gives the packager all the economy of polyethylene film – the least expensive transparent wrap on the market.

In your plant, PETROTHENE 218 (density, 0.933; melt index, 3.0) makes the grade too. It has excellent melt flow and hot-melt extensibility properties which permit high haul-off rates (>200 ft./min.) and relatively thin-gauge films (0.5 mil). It has been treated for printability in line with the extrusion process at rates exceeding 150 ft./min. At moderate treat levels, ink adhesion is excellent.

PETROTHENE 218 is available in three formulations of varying slip level: PETROTHENE 218, unmodified no slip; 218-26 – medium-low slip; 218-27 – medium slip.

For more information or for technical assistance in providing your customers with all the advantages of overwraps made from PETROTHENE 218, contact U.S.I.

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N. Y.
Branches in principal cities



DIAMOND PVC...

puts the SQUEEZE on hard-to-package materials

They're vinyl tubes extruded from Diamond PVC-450 resin. They provide an excellent barrier against oils, greases, paints and cements . . . and no special filling equipment is required of the packager. These characteristics make PVC-450 the logical vinyl for squeeze-tube packaging of such variables as lubricating oil, cosmetics, food products and medicinals. PVC-450 has an amazing use-record of faster extrusions with less power and lower production costs. Let us send you all the details on this versatile, UL-approved resin. Write Diamond Alkali Company, 300 Union Commerce Bldg., Cleveland 14, O.

Other Applications:

Calendering: Film and sheeting, luggage material, wall covering, upholstery, electrical and harness tapes, inflatable goods.

Extrusion: Wire insulation, gasketing, garden hose, sheet and tape stock, welting, medical tubing.

Processing: DIAMOND PVC-450 absorbs large quantities of plasticizers at a rapid and uniform rate to give dry, free-flowing powder blends. Unusually low gel content, with excellent clarity and heat stability, produces high-quality end products from either dry blend or pelletized compounds.

These squeeze tubes extruded by the Thatcher Glass Mfg. Co., Nashua, N. H., from compounds containing PVC-450 supplied by Electronic Rubber and Plastic Corp., Stamford, Connecticut.

Diamond Chemicals

Announces the Opening

of a

New

West Coast

Plant

At 3501 Giant Road

Richmond, California

for the production of

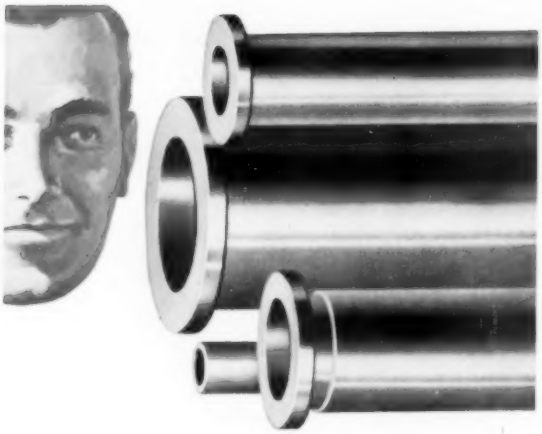
Polyester Resins

Polyester Resins are Our Business

Regardless of what the resin requirement is for your product . . .
our new West Coast plant or our Eastern plant and laboratories would like to show you how AAI resins can benefit you in production and in profit.

American Alkyd Industries

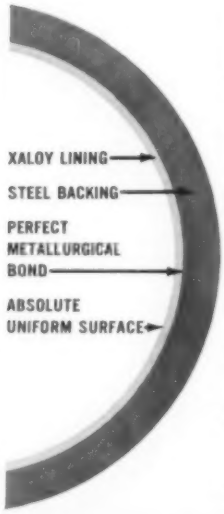
One of America's Foremost Producers of Synthetic Resins
Home Office: Broad & Fourteenth Sts., Carlstadt, N. J.
New West Coast Plant: 3501 Giant Road, Richmond, Calif.



only Xaloy

bimetallic cylinders can give you 25 years of proof!

For 25 years Xaloy extruder cylinders have ideally answered the corrosion and abrasion resistance requirements of the plastics and rubber industries. These integrally-bonded, mirror-smooth Xaloy linings are centrifugally-cast to provide the world's most advanced extrusion cylinders. We invite your inquiry concerning your individual specifications.



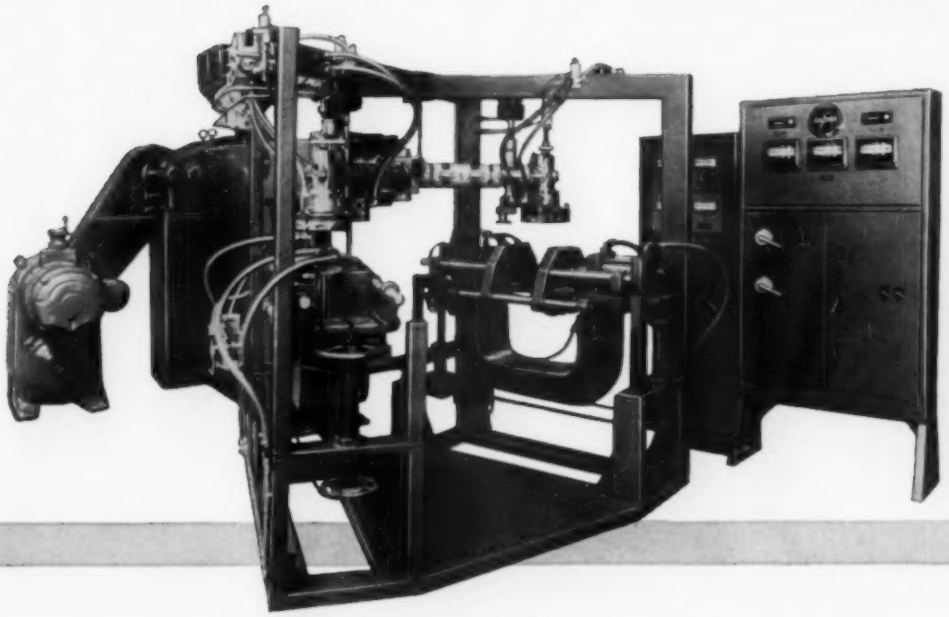
Xaloy . . . the original equipment on all leading extruders

Xaloy . . . the logical replacement for longest life

WRITE FOR XALOY DATA GUIDE

INDUSTRIAL RESEARCH LABORATORIES
Division of Honolulu Oil Corp.
961 East Slauson Ave.
Los Angeles 11, Calif.

Interested in Blow Molding?



MPM's new "Diversamatic" twin-station is the fastest, most versatile unit available.

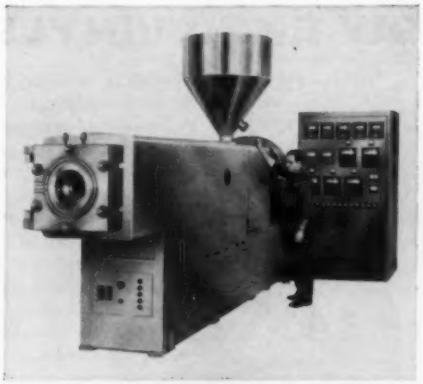
You owe it to yourself to check the advanced design features of MPM's new "Diversamatic" blow-molding machine.

Unique twin-station design lets you operate two identical or different molds at the same time. Once the machine is set up (easily done with manual controls), you switch over to automatic for high-speed, continuous operation.

You can produce single or vertically strung multiple-cavity work in lengths of up to nearly three feet! Materials blown include low- and high-density polyethylene, polypropylene, high-impact styrene, nylon and other materials.

The "Diversamatic" can be used with *any* extruder, domestic or foreign. If you wish, MPM will provide the *complete* unit, including extruder (see photo at right). Moreover, MPM will operate the unit for your inspection *prior* to shipment, then help you put it into operation in your plant.

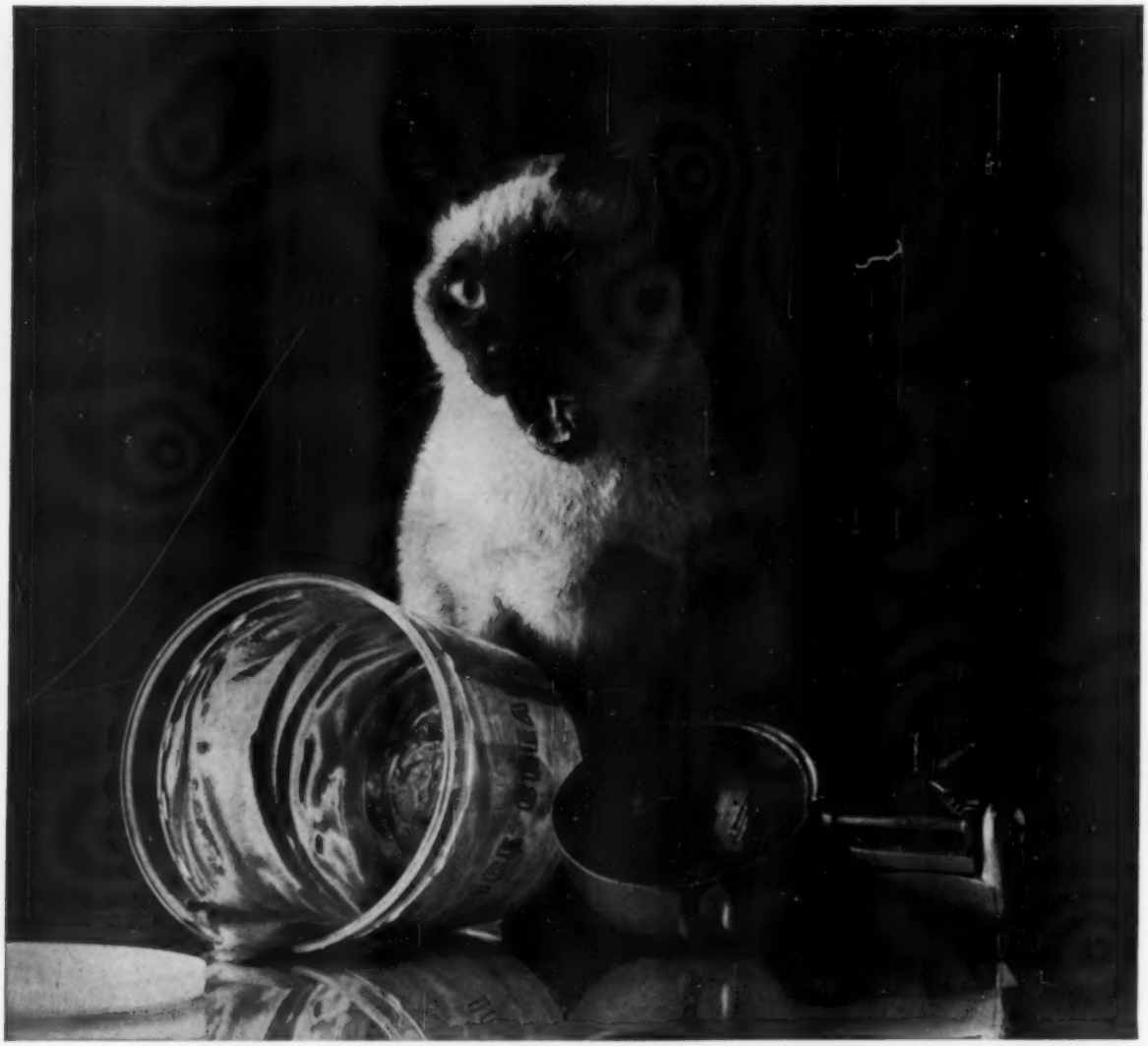
In addition to the "Diversamatic," MPM manufactures a one-station, two-head machine, two-station machines with either four or eight heads, and a new six-station *rotary* machine. For information on any or all of these, just drop us a note.



MPM COMPLETE PACKAGE UNIT includes an MPM extruder, "Diversamatic" twin-station blow-molding equipment, and the tooling, if desired.

Modern Plastic Machinery Corporation

General offices and engineering laboratories: 64 Lakeview Avenue, Clifton, N. J.



NOW RIGID VINYLS CAN BE MADE NON-TOXIC

Argus announces three new products—*non-toxic* stabilizers that *withstand the high heat needed to process unplasticized vinyl.* They provide stability superior to that of any non-toxic stabilizer previously available. All three are approved by the Food & Drug Administration.

The new, non-liquid stabilizers—Mark 33, Mark 34 and Mark 35—may be used in rigid compounds as the sole stabilizer system, and give excellent stability. They do not require the addition of epoxidized oils. Thus, they avoid the reduction in heat distortion temperature level and the loss of other important physical properties that occur with liquid-type stabilizers. They are suggested for use in extruded thin unplasticized film, rigid calendered sheet and plasticized non-toxic products.

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SPE JOURNAL

Every Month—the *significant* NEWS OF PLASTICS ENGINEERING

Non-Lubricated Bearings and Piston Rings of Tetrafluoroethylene

Roy B. Fehr, Jr.
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E. I. du Pont de Nemours & Co., Inc.

The forms and designs of bearings and piston rings utilizing TFE-fluorocarbon resins have progressed rapidly in the past few years. Now sound engineering and performance data are available so that the engineer can design with confidence where no lubrication is desired. As new designs have become available, the limits of performance have been extended, particularly in the case of bearings, and as research continues, these limits will be extended undoubtedly further.

The unique surface properties of tetrafluoroethylene (TFE-fluorocarbon) resins*, particularly their frictional properties, have received the attention of many investigators. One of the early investigations of TFE-fluorocarbon resins as solid lubricants was undertaken by the Naval Research Laboratory with enamels based on TFE resins as thin coatings on metal substrates. This led to the adoption by the Marine Corps of a thin coating of a TFE-fluorocarbon resin as a lubricant and preservative for small arms. The coating provided satisfactory lubrication for an almost indefinite period, and was also a suitable preservative for small arms for long term storage under adverse conditions (1).

Frictional Properties

Early investigators reported very low coefficients of friction for TFE-fluorocarbon resins, as low as 0.02. However conflicting results indicated that this low coefficient of friction was not maintained under all conditions. The apparent contradictions resulted from failure to take into account the effects of loading conditions and speed of sliding. This failure, in turn, was due to incomplete knowledge of the mechanism of friction, particularly in materials that deformed plastically as well as elastically at relatively low loads. The suggested theory now holds that the coefficient of friction depends not only on the bulk mechanical properties in the material, but also on surface geometry, on load, and on other sliding conditions.

When the many apparently contradictory studies of the coefficient of friction of TFE-fluorocarbon resins are combined into one curve, as given in *Figure 1*, the apparent contradictions disappear. The coefficient of friction decreases rapidly as the load increases in the 5 to 50 pound range. As the load increases above this range, the coefficient continues to decrease but more gradually. The continual decrease in coefficient with increasing load indicates that a TFE-fluorocarbon bearing surface will not seize even under extremely high loads.

Increasing the sliding speed increases the coefficient of friction rapidly as the sliding speed increases up to about 100 ft./minute under all load conditions, with higher loads producing lower coefficients (*Figure 2*). This increase in coefficient with increasing speed eliminates "slip-stick," or irregular movement. Above about 150 ft./minute, sliding speed has relatively little effect on the coefficient unless speed is so high that interfacial temperatures exceed the crystalline melting point of 620°F. Note that the filled composition, here under a five-pound load, exhibits a lower dynamic coefficient than would be expected of an unfilled TFE resin material under the same conditions. This phenomenon can be attributed to an increase in the hardness of the material. The same benefits have been obtained with other filled TFE compositions.

Of particular importance is the effect of temperature on the coefficient of friction as shown in *Figure 3*. The coefficient of friction is relatively unaffected by temperature up to the so-called crystalline melting point (620°F) of the polymer. Recent studies at cryogenic temperatures show that the same low coefficient of friction is maintained at these low temperatures. The low coefficient of friction at the very high temperatures indicates the superiority of TFE-fluorocarbon resins as a bearing material over other plastics (2).

* Sold by E. I. du Pont de Nemours & Co. Inc., under its registered trademark, "Teflon".

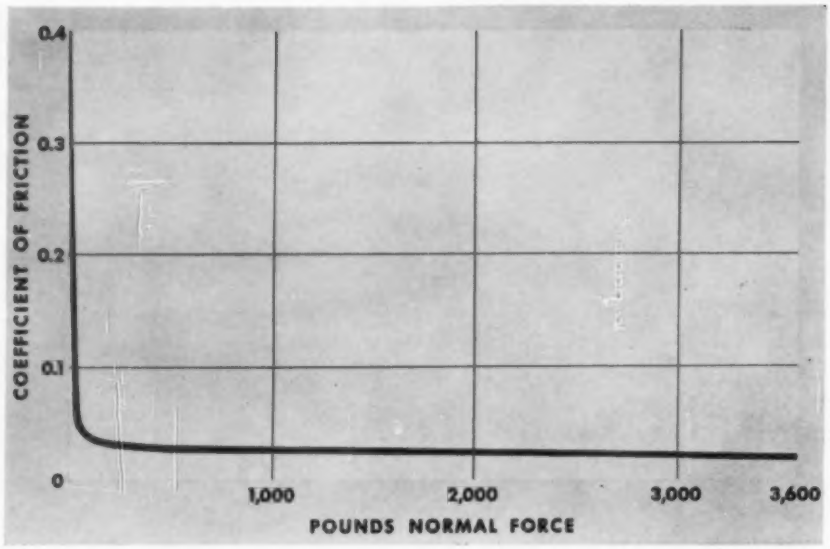

Figure 1. Effect of load on coefficient of friction (less than 2 fpm room temperature). Coefficient of friction decreases rapidly as load increases in 5 to 50 pound range.

Reinforced Molded Bearings

However, the excellent frictional properties of the unmodified resins are coupled with undesirable properties for bearing materials, namely, low mechanical strength (low resistance to creep) and low thermal conductivity. The overcoming of these deficiencies, without serious deterioration of the frictional properties, has resulted in the successful application of TFE-fluorocarbon resins in bearings and piston rings for non-lubricated service.

The usefulness of TFE-fluorocarbon resins in many applications can be considerably enhanced by additives or reinforcing agents such as graphite, copper, bronze, aluminum oxide, etc., and inorganic fibers such as glass, asbestos, and ceramic fibers. In addition, TFE resins can be molded around or on metallic screens to achieve a different type of reinforcement. These additives or reinforcements increase the resistance to deformation, the compressive strength, the thermal conductivity, and reduce the thermal coefficient of expansion. And most important for frictional applications, the resistance to wear by rotating or sliding shafts can be increased as much as 500 times.

The development of the use of additives in molding powders to make molded bearings, or reinforced shapes such as rods, tubing, and sheeting, has resulted in significant advances in non-lubricated bearing performance. For instance, one reinforced TFE resin composition has a coefficient of thermal expansion only one-sixth that of the resin alone. It has been reported to have been run unlubricated at PV values* up to 15,000 with wear rates less than 0.1 mil/hour.

This PV value is a significant advance when compared to the PV values of 1000 for unmodified fluorocarbon resins and PV values of 5000 for the early types of reinforced TFE resins (3).

Startling improvements in the performance of TFE resin bearings have been achieved by making the resin sleeve as thin as possible so as to facilitate the removal of frictional heat. This also reduces cost, thermal expansion effects, and creep. This approach is exemplified in one construction

* Note: The PV value is the product of the load on the projected bearing area in lbs./sq. in. and the surface velocity in ft./min. It is a measure of the heat generation rate and can be used as an approximation for designing over a range of loads and speeds. The higher the PV value, the better the performance or bearing capacity.

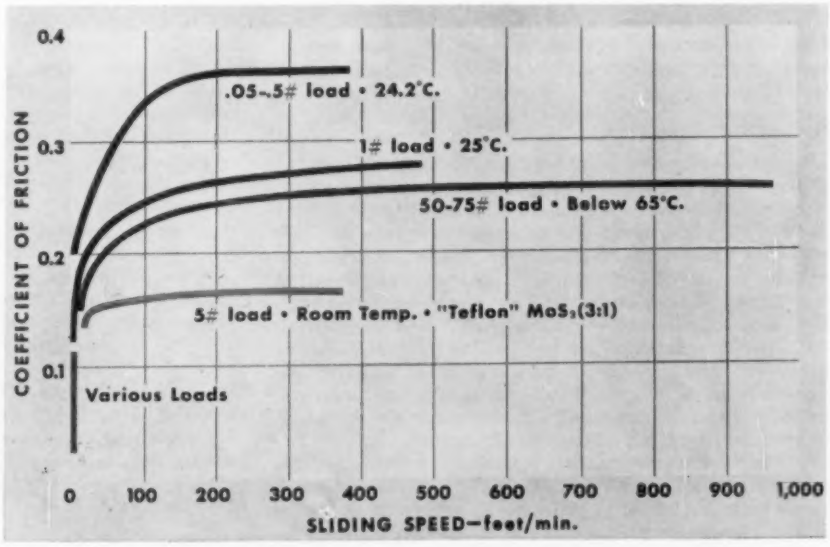

Figure 2. Effect of sliding speed. Coefficient of friction goes up rapidly as sliding speed increases up to about 100 ft./minute.

where reinforced TFE resins are impregnated on a 60-mesh screen. The coating thickness is about 6 mils on one or both sides of the screen. These liners can be backed by die-cast metal, fitted into rolled bushings, bonded to sheets, etc. PV values of 20,000 (unlubricated) are reported for these liners (4). The types discussed are typical but are by no means inclusive.

Thin Coatings as Bearing Surfaces

Bearing surfaces of the TFE-fluorocarbon resins have the unique property of transfer as very thin films to mating surfaces. In addition, the TFE resins can be "smeared" across surfaces as ultra-thin films. This property is used advantageously in another system where particles of a TFE resin are bonded by resins such as the phenolics, either by molding the phenolic or casting the phenolic in a liquid system with the fluorocarbon resin. As with other systems, increased resistance to deformation and wear are achieved. In addition, the coatings or molded parts can be "cured" at room or moderate temperatures compared to the 700-750°F curing or sintering temperature required for fusing TFE-fluorocarbon resins (5).

Liquid resin systems, incorporating a TFE-fluorocarbon resin dispersion, are now available. Thin films in the order of one to two mils in thickness can be applied to irregular surfaces and to heat-sensitive materials such as rubber, wood, plastics, paper, etc. The frictional properties of these resin coatings compare favorably with those of films of TFE-fluorocarbon resins alone. In addition, the wear life is improved by at least a factor of two over unmodified coatings of TFE resins for practical loads and speeds (6).

Impregnated Bearings

Bearing materials have also been developed based on porous metal impregnated with TFE dispersion. Such bearings may consist of a tin-plated steel backing on which is bonded a layer of bronze impregnated and coated with a mixture of TFE-fluorocarbon dispersion and lead. The addition of the lead increases the wear resistance of the bronze impregnated with resin alone and permits the bearing to handle increased speeds and loads successfully. In common with other bearings of TFE resins, no "slip-stick" characteristics are found in this type of bearing. The coefficient of friction ranges between 0.01 and 0.16 for loads ranging from 10 p.s.i. to 1500 p.s.i. and for speeds from 40 ft./minute to about 1,000 ft./minute. These bearing materials also have relatively high thermal conductivity and low thermal expansion (7).

Table 1. Relative Properties of TFE Fiber, TFE Resins and a Textile Grade of Nylon

	TFE Fiber	TFE Resins	Nylon Fiber Type 200
Filament diameter	0.008	—	0.0062
Density (grams/cc)	2.2	2.2	1.14
Tensile strength Lbs./sq. in.	47,000	3,000-5,000	61,000
Elongation at break	13%	200-500%	26%
Initial Modulus Lbs./sq. in.	471,000	60,000	264,000

TFE Fiber Bearings

Highly oriented fibers of TFE resin are commercially available. As shown in *Table 1* the fibers have superior mechanical properties as compared to the molded resins. They are used in packing, filtration cloths, electrical insulation, and gaskets. As a bearing material, fabrics of TFE-fluorocarbon fiber have been used successfully in journal, plain surface, spherical, and ball and socket type bearings.

Figure 4 provides an indication of typical speed and load conditions for sleeve bearings of TFE resin fabrics where continuous operation without lubrication is desired. Plastics and sheet metals have been used effectively as a housing for such bearings. The superior load bearing capacity of TFE fibers as compared with porous bronze can be readily seen by referring to *Figure 4*. This and other experimental work indicate that bearings of TFE fiber are almost ideally suited for conditions of high load and slow or intermittent sliding speed such as encountered in automotive suspension and steering linkage systems. In applications where very slow oscillating or sliding speeds are involved, bearings of TFE fiber are successfully used without lubrication at loads up to 60,000 p.s.i.

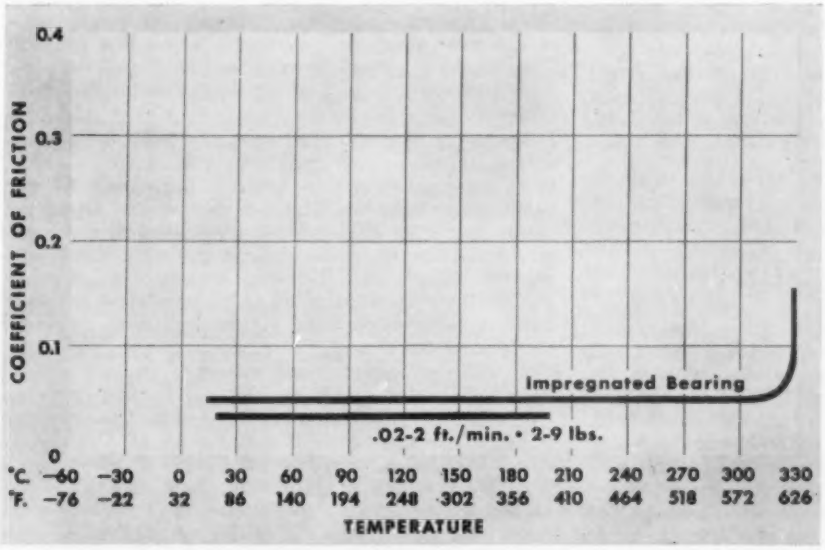

Figure 3. Effect of temperature. Coefficient of friction is relatively unaffected by temperature up to the so-called crystalline melting point (620°F.).

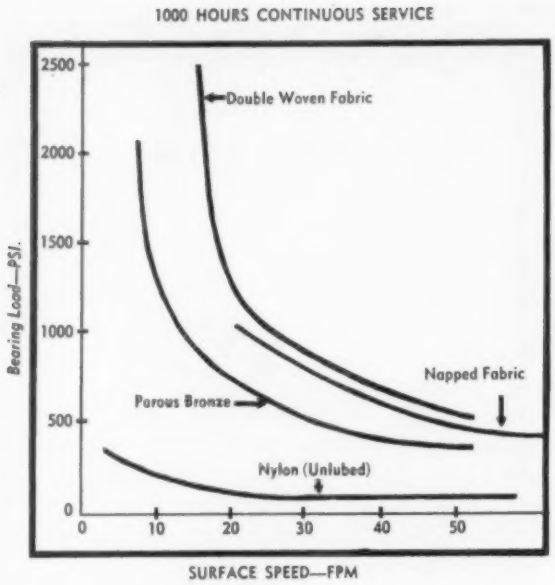

Figure 4. TFE fibers have superior load-bearing properties.

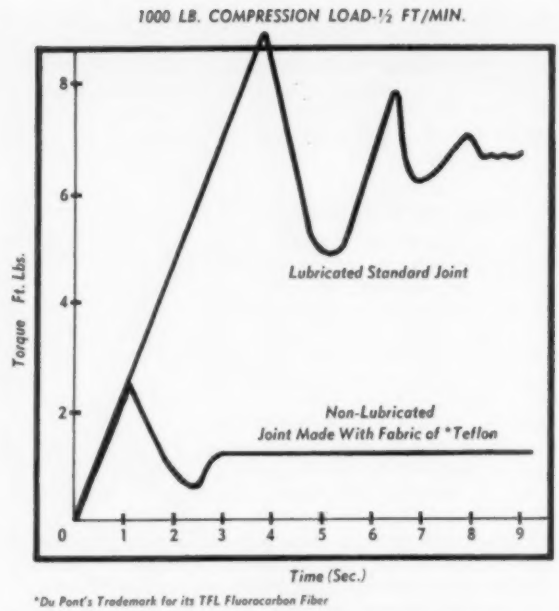

Figure 5. Comparison of frictional characteristics of conventional lubricated ball and socket suspension joint and similar unlubricated joint made with fabric of TFE fibers.

A comparison between the frictional characteristics of a conventional lubricated automotive ball and socket suspension joint and a similar unlubricated joint made with fabric of TFE fibers is shown in *Figure 5*. The joints were placed under equal loads and put into a rotational motion by a force being applied at constant rate. The standard joint required a force of nine pounds to break away, and after a few rather severe fluctuations, the force required to maintain the motion leveled off at 6.5 pounds. The joint made with fabric of TFE fibers exhibited much easier and smoother operation, requiring but 2.5 pounds of force to break away and a force of only 1.2 pounds to be kept in motion. The non-lubricated joint operates smoothly, while the standard joint suffers the characteristic jolts of "slip-stick."

In another interesting test the performance of fabric of TFE-fluorocarbon fiber in spherical bearings under high-load, low-speed oscillating service was made. The initial test was carried out with a 60 degree arc of oscillation, a frequency of 60 cycles per minute and 3,000 p.s.i. load. The TFE fiber bearing received only initial lubrication whereas the all-steel bearing was lubricated every 24 hours.

The test was stopped at one million cycles due to scoring and excessive temperature of the all-steel bearing. The TFE fiber bearing showed evidence of wear, but was still operating satisfactorily. Similar results were observed in the test at 16,000 p.s.i. At 25,000 p.s.i. the all-steel bearing seized shortly after start-up, whereas the TFE fiber bearing was in serviceable condition after 6,000 cycles (8).

New bearing materials of fluorocarbon resins have greatly extended the performance of non-lubricated bearings and are finding many new applications. The specific choice of bearing material depends on the particular application. Extensive testing in the laboratory and in the field have developed important practical design information for each type of bearing to assist design engineers in the application of any particular bearing. As with any new material, particularly in an application as critical as a bearing, careful designing and testing must be done to insure satisfactory performance and the correct application of the bearing.

Piston Rings

Since their introduction as commercial products TFE-fluorocarbon resins have been used in mechanical or moving seals. For instance, pump seals of TFE resins are used because such seals make these pumps universal in application.

Piston rings of fluorocarbon resins have been used in aircraft industry for many years. In these applications, temperatures are high and break-away friction must be kept extremely low. Floating rings of TFE resins have replaced rubber "O" rings in hydraulic control cylinders and decreased the frictional forces by as much as 15 per cent. "Slip-stick" action is entirely eliminated while maintaining leakage rates almost as low as with the rubber "O" rings. Cylinders operate more smoothly and the life of the piston rings is much greater than the life of the replaced "O" rings.

The use of rings of TFE-fluorocarbon resins in lubricated service and the natural lubricity of these resins quickly led to an investigation of these resins in piston rings for non-lubricated service. Non-lubricated compressors are of particular interest to chemical and related industries because of their ability to handle difficult process gases such as chlorine, oxygen, and hydrogen. Perhaps even more important, the elimination of oil as a contaminant in process gases or fluids is desirable in pharmaceutical, food, and chemical processes.

A variety of materials such as carbon-graphite are used for non-lubricated piston rings. However, such rings are fragile and/or subject to excessive wear and breakage, resulting in expensive down time and overhaul. Although the desire to eliminate or reduce lubrication in compressors is high, the materials to do this job, heretofore, have been limited in application. The advent of TFE-fluorocarbon resins and particularly the ability of TFE-fluorocarbon

Table 2. Wear Rates of Various Materials Against Steel, Non-Lubricated Room Temperature, 751 ft./min., 102.4 p.s.i.

Material	WEAR RATE Inches/Hr. x 10^{-6}
TFE fluorocarbon resin, fiber glass filled	25
Carbon-Graphite	27
TFE, graphite filled	34
TFE, ceramic filled	35
TFE, laminated glass filled	52
Nylon	120
Laminated cloth phenolic w/graphite	310
TFE, asbestos filled	340
Polyethylene	410
TFE, no filler	6000
TFE, molybdenum di-sulphide filled	9240

Source: France Packing Co., Phila., Pa.

resins to be reinforced for improved wear and resistance to deformation have led a number of companies to investigate the use of these resins.

Wear Tests

In early stages, the development of piston rings of TFE resins involved laboratory tests on various reinforcing additives. A typical study is shown in *Table 2*. This test consisted essentially of a weighted rider, containing the piston material under test, riding on a drum driven by an electric motor. Test samples measured ⅝" by ⅝" by ⅛" and were held in two separate arms and loaded by adding weights at the ends of the arms. Very high unit pressures were obtained in this manner (9).

Blends of glass and TFE-fluorocarbon resins indicated the least wear, followed by carbon-graphite. As with most laboratory tests, these data give only an indication of performance. The first five materials are all considered to be satisfactory materials for piston rings. It is interesting to note that, at high ambient temperatures, this test and tests by other piston ring manufacturers have indicated that the carbon-graphite rings generate considerably more heat than rings of TFE-fluorocarbon resins.

Table 3. Wear Tests. K-30* vs. Various Cylinder Materials

Wear Test Drum Material	Wear, Milligrams, Weight Loss One Hour, Room Temperature K-30 Rider	Drum
Cast Iron	1.6	0.3
316 Grade Stainless Steel	2.8	0.8
410 Grade Stainless Steel	2.0	0.6
Nitrided 4140 Steel	2.4	1.8
Dense Chromium Plate	13.9	7.1
AMS 7322A Bronze	1.1	24.1
319 Aluminum Alloy	24.5	22.3
M377 Aluminum Alloy	51.9	23.2

Source: "Development of TEFLON Based Piston Rings by Taber & Robbins," presented at ASME Meeting June, 1957.
* KOPPERS Company Trademark for TEFLON TFE resin and Glass composition.

Equally important as the wear on the piston ring is the wear of the cylinder wall. In *Table 3* is reported typical cylinder wear data for a piston ring of reinforced resin against cylinder walls. The wear obtained when running against the aluminum-alloy drum is comparatively high. However, TFE resins appear to be among the few materials that can wear directly against aluminum without lubrication (10).

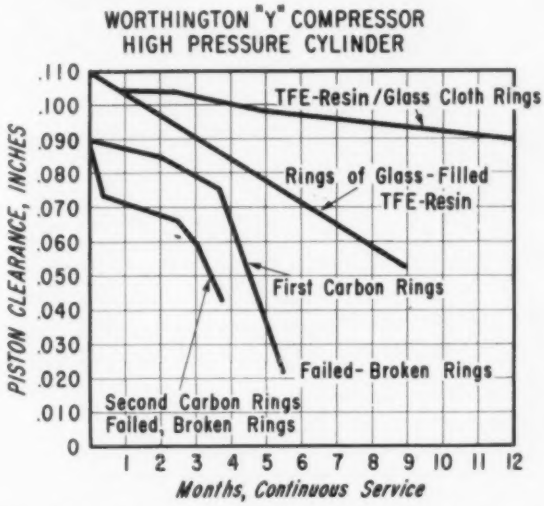

Figure 6. Wear results. Carbon piston rings and wear rings vs. TFE-resin/glass cloth piston rings and wear rings.

Applications of Piston Rings

Life tests of two types of piston rings of TFE-fluorocarbon resins as compared to carbon-graphite rings are shown in *Figure 6*. These tests were run to determine the technical and economic factors on the use of piston rings of TFE resins. Although rings made from glass cloth impregnated with TFE resin perform better than the molded rings, the difficulty and costs of making laminate rings have led generally to the use of molded rings. It is also true that test results in this type of practical testing are not always translatable to other machines and conditions.

The plant reporting these data has standardized on rings of fluorocarbon resins for its air compressors. Other plants have reported even more successful performances. One plant reports it has decreased wear by a factor of four when going from rings of carbon-graphite to rings of TFE resin. Several plants have translated the successful performance obtained in air service to process compressors handling such things as chlorine and inert gases such as nitrogen and carbon dioxide. Another important consideration is that plastic rings are soft enough so that no damage to the compressor liner results if ring breakage occurs.

During the last few years many installations have been made and tested as shown in *Table 4*. The compressor services include air, dry nitrogen, carbon dioxide, and pump services on hydraulic fluid and cold liquid oxygen. Included in these case histories are rings up to 15 inches in diameter, speeds up to 1800 ft./minute, pressures to 2400 p.s.i. and temperatures ranging from —320° to 350°F. A bone-dry gas such as listed in the third item represents severe service due to the absence of moisture in the gas, which normally contributes to lubricity. In each case, the wear rate and service life are improved from double to 50 times the previous material used (11).

Table 4. Performance Data-Piston Rings of Reinforced TFE Resins*

COMPRESSOR	Bore	Average Piston Speed	Inlet Press.	Exit Press.	Exit Temp.	Process Mat'l	RESULTS
		(Ft/Min)		(Psi)	(°F.)	AIR	
Single stage, non-lubricated, horizontal	9"	600	Atm.	100	350	(H_2O Saturated)	Wear rate: 0.0024"/1000 hrs. less than half that of best competitor
Single Stage, non-lubricated	14"	365	Atm.	100	350	AIR (Sat'd)	Wear rate: 0.002"/1000 hrs. at 5 months; test still in progress
Single stage, non-lubricated	7"	467	—	100	—	Nitrogen (Bone dry)	Wear rate: 0.001"/1000 hrs. one 35th that of nearest competitor
Second stage of non-lubricated	1½"	467	700 psi	2400	350	AIR	Still in service after outlasting carbon rings 50 to 1
Single stage, double acting, converted to non-lubricated service	10"	550	Atm	125	>350	AIR	Wear rate: 0.002"/1000 hrs. at 1½ years. Prevents fouling of instrument air lines and instruments
Hydraulic torque converter	8"	1800	ΔP = 350 psi		250	Hydraulic Fluid	With cast iron wear plate outlasted 4 sets of other combinations
Vibrator unit		375	Atm.	70-90	300	AIR	Ring life 1 year minimum. Lubrication, maintenance, contaminated air discharge eliminated
Single stage, water lubricated	7"	210	Atm.	250	100	CO_2	Still in service after 2 years
Single stage, non-lubricated	15"	500	Atm.	100	350	AIR	Negligible wear at 1½ years, indicating life twice that of carbon rings
Reciprocating immersion pump	¾"	(4.5 gpm)	—	—	−320	O_2(liq.)	Excellent test results—rings adopted for commercial production of pump
AND MANY OTHERS							

* Data Courtesy of Koppers Co., Metal Products Division, Baltimore, Md.

Design Considerations

In designing compressors to use rings of TFE-fluorocarbon resins and in the design of the rings themselves, two important basic considerations must be weighed: (1) Reinforced TFE resins have three to five times the thermal expansion of steel. Thus allowances must be made for thermal expansion of the rings; (2) The thermal conductivity of TFE resins even when fillers are incorporated is quite low. Therefore, provisions for the removal of any excessive heat must be considered. Although TFE-fluorocarbon resins retain their low coefficient of friction up to temperatures as high as 600°F and will operate in piston rings up to temperatures of at least 400°F, the rate of wear does increase as the temperature rises. Therefore, it is advantageous to keep the frictional heat low by removing it through the cylinder or piston walls.

In view of the above considerations and due to the lower strength of the plastic rings as compared to metal rings, rings of TFE resins are usually wider than corresponding metal rings. In contrast, the plastic rings are usually thinner than carbon-graphite rings.

Lubricated Service

Rings of TFE resins are used in lubricated service to reduce the lubrication or reduce the wear of the cylinder walls. Tests in diesel engines have shown that rings of TFE resins can perform satisfactorily in these engines and reduce oil consumption. More recently tests have been underway on the use of such rings in gasoline engines.

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Reinforced Plastics in Missiles and Rockets

J. J. Mobilia and D. V. Rosato
Raytheon Manufacturing Co.

Reinforced plastics are a dream material for the missile designer. Different type materials can be developed to meet numerous environmental conditions.

Since World War II there have been spectacular developments in the plastics field and in particular, the reinforced plastics field. Originally, most of the R & D programs were related to electrical requirements with increasing emphasis on developing structural parts based on improved design parameters and improved fabrication techniques. Modifications in the specialty plastics materials have continuously been made which in turn have developed improved fabrication techniques, reduced rejection rates, increased various properties, and helped reduce cost of parts through the process of simplifying the design or tooling required to produce parts.

One of the more interesting aspects of reinforced plastics is that *they can be infinitely modified to meet end use requirements.* Design and application engineers can use reinforced plastics for fabricating parts which in some cases are impossible to produce out of metals. Variation in resin, reinforcing materials, fillers, or their ratios result in variation of the physical form of the cured material; curing cycles or ingredients can be varied; fabrication techniques are numerous and in some cases complicated. These different conditions produce different type materials which in turn permit the development of different type hardware to meet the numerous environmental conditions.

Fibers and Composites

By far, glass fiber-reinforced plastics are the largest single type product available and useful both in aircraft, missile, and other industries. Glass fibers are used in molding compounds, cloth, tape, yarn, and roving with principally organic type resins. New developments with inorganic resins and ceramic type compounds have definitely increased the maximum temperature properties. Typical binder systems include silicones, phenolics, Tri-Ester polymers, glass frits, epoxies, polyesters, and graphite.

Fibrous glass is comparatively low in density, stiff, chemically resistant, not expensive, suitable for textile manufacturing techniques, capable of expensive modifications by composition changes, and useful at elevated temperatures. Recent developments have produced modified fibrous glass which basically has increased the strength and stiffness of the fibers. Values of 20 million psi for tensile modulus are being obtained. Primarily for these reasons, there has been demonstrated a growing importance in structural applications during the past years. Now many functions essentially impossible with other materials in missile hardware are performed.

Other fibrous structures have been found to be useful in missile parts. These fibers include regular and leached asbestos, leached glass, quartz, nylon, graphite, and ceramic. Even cellulosic fibers have been found to be useful in different applications. Cellulosic fibers as well as other fibers coated with different type fibers which include regular fibrous glass and leached glass fiber appear to be well suited for the fabrication of different parts.

It is important to recognize that in many of the external or motor body parts where reinforced plastics are used, structural consideration has generally been of a secondary requirement. However, more development programs are now in process to improve fabrication techniques, and thereby, produce more reliable parts where structural requirements are as important as the thermal requirements.

In regard to fibrous construction, many of today's applications incorporate the use of combination fibers such as glass with nylon, graphite with asbestos, etc. These composite fibrous structures take advantage of the individual distinctive properties and produce marriages which have dis-

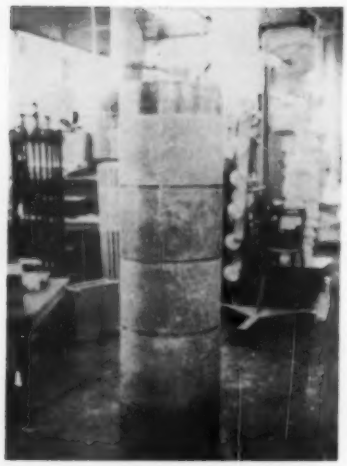

Figure 1. ICBM Ablative Coating on Glass Filament-Wrapped Motor Body

Figure 2. Composite Structural Missile Fin Involving Heat Insulator and Structural Members

tinct advantages. The glassy compositions involving low melt glass will produce a melting condition at the extreme high temperatures. Mineral type fibers will produce a non-melt condition and in some cases will produce a refractory type structure.

Where high temperature requirements exist, ablative or insulating plastics bodies can be developed for use where heat and structural requirements exist (*Table 1*). The matrix such as Tri-Ester Polymers can produce a complex thermal condition which involves absorbing energy to complete one or more endothermic physical and chemical reactions (sublimation and energy of disassociation respectively). These ablation materials can absorb the energy supply from external sources and transforms from a solid directly or indirectly into several gases. Composite structures can be developed which will not carbonize and therefore have applications where electrical requirements also exist.

Different type woven fabrics are commercially available which incorporate one or more basic fibers. These fabrics can be used by conventional fabricating techniques or can be modified to take care of tape wrapping at an angle in tubular forms. Woven fabrics can be considered a standard product which in turn can be treated with different binders to produce missile parts.

Non-woven fabrics have been developed to produce high strength, heat resistant, chemical resistant, electrical grade and/or other important properties required in missile applications. A non-woven fabric is a textile-like product in which the fibers are held together with a mechanical lock or a bonding material. These paper and felt products are made up of matted fibers in automatic equipment. Different type fibers can be processed, but more development is required in developing the most efficient non-woven products for industry.

The non-woven fabrics can be produced with isotropic or orthotropic properties in the direction of the heat. Interesting aspects concerning non-woven fabrics involve theoretical and practical determination of engineering properties. With certain type fibers, it is a simple matter to develop three times the strength available in the same type fibers when used in woven fabrics. This particular engineering variation generally has not been noticed with these specialty fibers. This subject is relatively new and will definitely provide the development of increased high strength fiber products by using non-woven fabrics (papers, felts, etc.).

In addition to using fibers for molding compounds, fabrics and non-woven fabrics, they are definitely suitable for producing sprayable type insulation in missile hardware. It is universally recognized that chopped glass spray techniques produce useful parts both for military requirements and in particular, commercial requirements. However, other type fibers such as graphite and asbestos can produce extreme heat-resistant insulating products.

Other type plastics applicable in reinforced products which are developing useful parts include boron compounds, polyoxymethylene, teflon-bonded ceramic fibers, glass and quartz microspheres, sintered nylon and teflon, chlorinated polyether, diallylphthalate, acrylic resins, and polyethylene.

Reinforced plastics are also useful in developing alternate plies of brittle and ductile materials made up of ceramics, refractory metals and inorganic or organic binders. These types of composite structure products are sintered under high temperature and pressure to form heat resistant and structural parts. The random orientation of slip planes in this composite will improve the ductility of thin layers of ductile materials which will produce high temperature properties.

Table 1. Approximate Physical Properties of Various Protective or Ablative Coatings

Material	(1) T_A(°F)	(2) Q_D(BTU/LB)	(3) C(BTU/LB°F)	(4) ρK (BTU-/LB-HR FT°F)
Teflon (High Density)	1100	689	.25	19
Fiberglas (Phenolic)	3000	750	.40	25.5
Nylon (Phenolic)	1400	1500	.35	22
Polyethylene	775	1089	.55	11.8
Teflon (Low Density)	1100	689	.25	2.0
Tri-ester Polymer	4000	5000	.28	22

(1) Temperature of ablation, T_A, °F.
(2) Heat of decomposition, Q_D, BTU/LB.
(3) Specific heat, c, BTU/LB-F°.
(4) Density, ρ, LB/FT³ and thermal conductivity, k, BTU/FT-HR-F°.

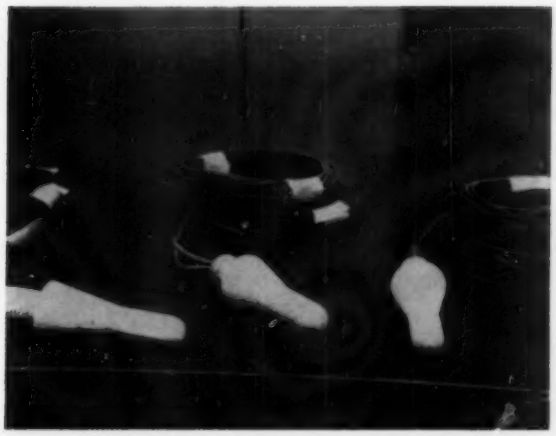

Figure 3. Missile Nose Cone Involving the Use of Heat Resistant-High Strength Reinforced Plastics

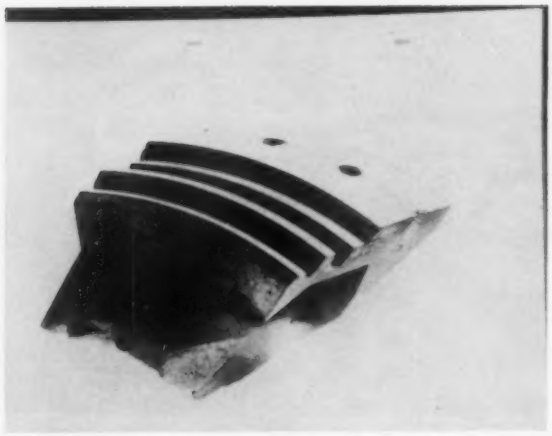

Figure 4. Quartz-Asbestos: Graphite Composite Construction of ICBM Nozzle Throat

Heat Absorption

Probably one of the major publicized properties which makes plastics desirable for missiles involves heat absorptive properties. This characteristic may be defined as the art to match an environmental heat flux with an absorptive heat flux of equal magnitude at the surface of the material in a missile. Heat may be transferred to the surface of a body by one or more three ways: radiation, conduction, or convection. Various plastics materials are now used in heat absorptive areas. To see why reinforced plastics greatly interest the designer, see *Table 2*.

Table 2. Thermal Conductivity of Various Construction Materials

Materials	BTU/HR/SQ.FT./°F/IN.
Reinforced Plastics	.75 to 1.25
Titanium	100 to 140
Aluminum	840 to 1560
Stainless Steel	100 to 170
Copper	2500

Missile Parts

Probably three of the more obvious reinforced plastics applications in missiles involve the motor body, (*Figure 1*), fins (*Figure 2*), and nose cone (*Figure 3*). In regard to producing insulation, ablative or heat resistance protection on either metal or reinforced plastics structure, developments have been made whereby a composite structure is produced which provides for overall structural efficiency, thermal requirements, and produces a lighter weight structure. R & D programs in this area are numerous and will definitely be instrumental in developing more reliable reinforced plastics parts.

In the case of fins, there is a gradual change from all metallic base structures to composite metal and plastic sandwich constructions. The advancement in the use of plastics is directly the outgrowth of increased temperature requirements on products which inherently have structural strength properties.

All reinforced plastics motor bodies with filament wound or tape wound structures is now reaching a stage where production items are being produced. Increased develop-

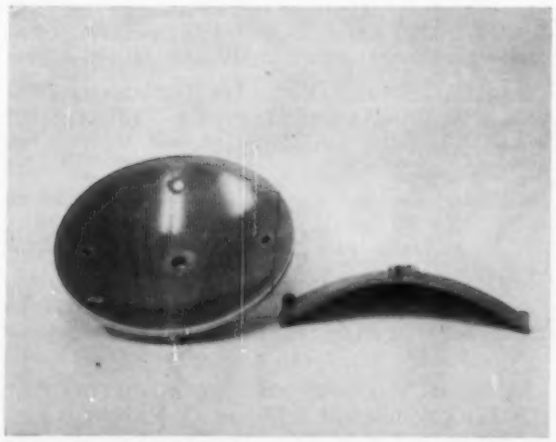

Figure 5. Missile Nose Cone Polarized Grating for Search Type Installation

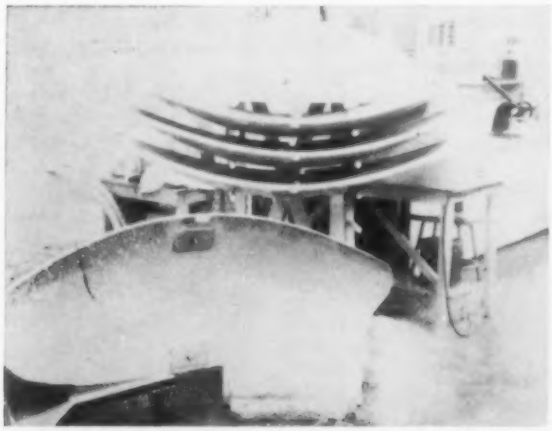

Figure 6. Supersonic Aircraft Reflector

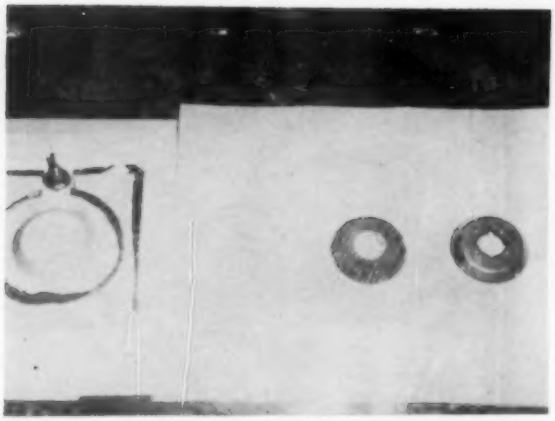

Figure 7. Composite R. F. Grating—Subassembly

ment effort in regard to design and fabrication has occurred in order to achieve the potential strength of filament or tape units which can be processed satisfactorily in order to produce complex pressure vessel configurations.

In regard to composite throat sections for rocket motor bodies, *Figure 4* shows a combination of a reinforced asbestos-graphite construction. This type combination of materials typifies the suitability of incorporating plastics insulators behind heat resistant materials such as graphite, molybdenum and other similar high temperature refractory materials used in throat sections of long burning extreme high temperature ICBM hardware.

Another important reinforced plastics product used in missiles and aircraft involves special reflectors which will meet electrical, structural, and limited temperatures. *Figures 5, 6 and 7* typify reflectors in this category. These reflectors were redesigned so that the original (practically all) metal structures were replaced with all plastics. The reflectors incorporate composite materials such as glass fiber, asbestos, epoxy, and phenolic resin, Hycar and honeycomb core, silicone foam, copper grid lines, etc. Fabrication techniques incorporate combinations of compression molds, bag molds, vacuum deposition, filament wrapping, and extrusion. Extreme close electrical and mechanical tolerance must be met in these parts.

In *Figure 8*, a typical complex air duct is shown. This part actually consists of 853 individual units. It is a very lightweight unit and requires that close mechanical tolerances on relatively thin sections exist. The part must withstand 18 lbs. of pressure per square inch under water. It has replaced metal ducts based on approved thermal and structural properties as well as simplification of fabrication.

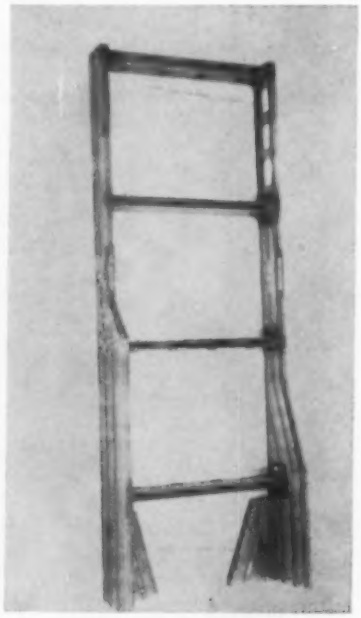

Figure 8. Complex Air Duct—Reinforced Plastics

Conclusions

The performance of reinforced plastics materials in missiles based on requirements of high temperature, structures, chemicals, ease of fabrication, and other conditions permits its use in many different parts such as those explained in this paper as well as some of the unseemingly spectacular parts. These other parts include electrical connectors, internal insulation bulkheads, encapsulation of delicate equipment or instruments, specialty gaskets, etc. It is important to recognize that the general routine basic data available on plastics can sometimes hinder profitable use of the base materials in composite structures. Parts have been successfully evaluated and incorporated in production based on highly engineered assumptions.

Plans are now in operation for developing saucer-like platforms which would be stationed miles above the earth for long periods of time. Scientific breakthroughs will be occurring, and these platforms will definitely incorporate reinforced plastics. It is important that R & D programs on basic material studies be made, so that more of the complex environmental problems in missiles be met with composite-reinforced plastics.

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Low Melting HET-Hexahydrophthalic Anhydride Mixtures

Hardeners for Epoxy Resins

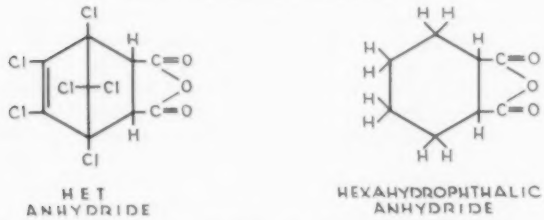
C. S. Ilardo and B. O. Schoepfle
Hooker Chemical Corp.

A system for making fire-resistant epoxy resins

Anhydride curing systems for epoxy resins are finding increased acceptance because of the advantages which they can confer. Through judicious choice, anhydride curing agents can be selected to give low toxicity and excellent high temperature characteristics. A further advantage of cost reduction can often be realized from high molecular weight anhydrides since they may be relatively inexpensive and are usually employed in much greater quantities than are common with amine systems.

Many of the previously mentioned advantages plus fire resistance can be achieved with systems containing (1, 4, 5, 6, 7, 7-hexachlorobicyclo (2.2.1)-5-heptene-2, 3-dicarboxylic anhydride), which is also known as chlorendic anhydride or HET* anhydride (see structural formula), the name by which it will be hereafter referred to in this paper.

STRUCTURAL FORMULAE



* Trademark, Hooker Chemical Corporation

HET anhydride is a high melting solid which can be formulated with approximately equal quantities by weight of liquid-type resins to give fire-resistant systems with ASTM D648-45T heat distortion temperatures of about 200°C(1). In certain applications, the high melting characteristics of such anhydride hardeners have been found troublesome since these systems generally require heat to effect solution of the hardener in the resin. This problem can be materially reduced or eliminated by the use of a coanhydride which forms a eutectic mixture with the high melting anhydride hardener. The resulting systems can have melting points which are lower than either of their components and if chosen correctly can provide a means by which the benefits of anhydride curing systems can be obtained with no sacrifice of handling properties.

Preliminary studies concerning the use of HET-coanhydride systems have previously been reported (2, 3, 4); however, it is the purpose of this paper to more fully explore the possibilities of such systems and to present data which will be of assistance in their use.

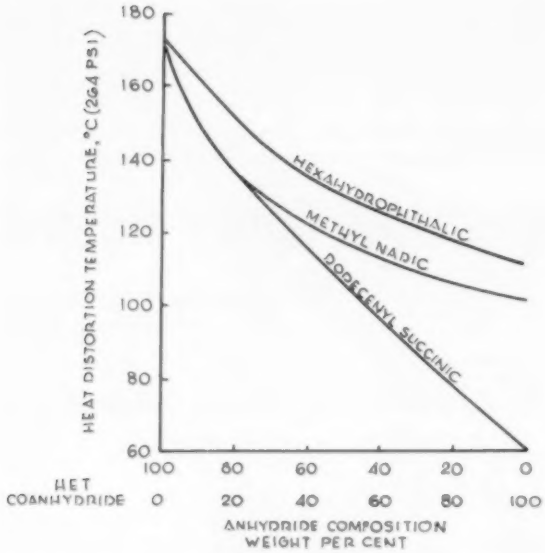
HET-Coanhydride Systems

It is highly probable that almost any liquid anhydride curing agent could be used to advantage in a HET-coanhydride curing system; however, the availability and price of such materials limits practical considerations to those listed in *Table 1*. If liquid or nearly liquid systems are de-

Table 1. Physical Characteristics of Various Anhydrides And Their Solidification Temperatures with Several Ratios of HET Anhydride

Anhydride	Empirical Formula	Molecular Weight	Melting Point, °C	Solidification Temperature (°C) with HET					
				100/0[b]	80/20	60/40	40/60	20/80	0/100
HET	$C_9H_2O_3Cl_6$	371	239-240	238	—	—	—	—	—
Hexahydrophthalic	$C_8H_{10}O_3$	154	35-36	238	114-115	74-75	15	15	35-36
Dodecenyl succinic	$C_{16}H_{26}O_3$	266	12	238	104-105	66-67	10	10	12
Methyl Nadic[a]	$C_{10}H_{10}O_3$	178	12	238	115-116	89-90	15	10	10
Phthalic	$C_8H_4O_3$	148	131	238	—	108	—	—	131
Maleic	$C_4H_2O_3$	98	53	238	—	86	—	—	53

[a] Trademark, Allied Chemical and Dye Corporation
[b] Weight ratio: HET/coanhydride



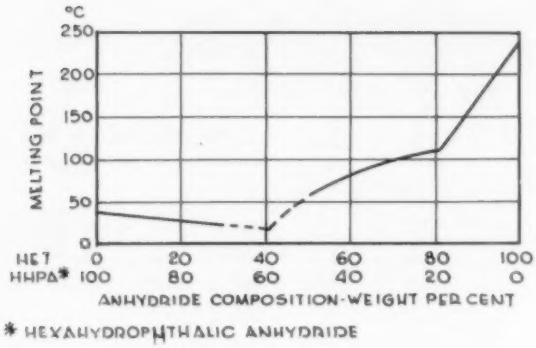


Figure 2. Melting point diagram for HET-hexahydrophthalic mixtures (uncatalyzed)

◀ **Figure 1.** Heat distortion characteristics of Araldite 6020 curved with HET-coanhydride mixtures (1:1 anhydride-epoxy equivalence ratio) containing 0.5% catalyst (α-methylbenzyldimethylamine) (20-hour cure at 180°C.)

sired, it is apparent that the choice of the coanhydride component is limited to hexahydrophthalic, dodecenyl succinic, or Methyl Nadic anhydrides. The heat distortion-composition characteristics (*Figure 1*—only the 120° cure curve is shown, but it is typical of the 100 to 180°C cure range) of these systems at cure temperatures of 100 to 180°C indicate that hexahydrophthalic anhydride shows the most promise for use in HET-coanhydride systems.

HET-Hexahydrophthalic Anhydride Systems

General Characteristics

Figure 2 shows that the eutectic for HET-hexahydrophthalic mixtures is at a weight composition of about 45 percent HET and that this mixture will remain liquid for about 8 hours at 23°C. With the incorporation of 0.2 to 1.0 percent α-methylbenzyldimethylamine, the system remains liquid for more than 24 hours at 23°C.

Coanhydride systems utilizing HET-hexahydrophthalic mixtures provide epoxy formulations having a wide range of fire resistance characteristics as well as heat distortion temperatures. The systems are non-toxic and relatively low in cost. Their properties are dependent upon the coanhydride ratio as shown in *Figures 3 and 4*.

It is apparent that increased HET-coanhydride ratios give epoxy formulations which have higher heat distortion temperatures and lower burning rates, according to ASTM D757-49T, a method for evaluating self-extinguishing type plastics. These burning rates can be materially reduced, as shown with Araldite† 6020 (*Figure 4*), by the incorporation of small amounts of antimony oxide into the formulations.

These data, obtained with catalyzed Araldite 6020, Epon 828,** and DER-332,†† are considered as typical and can be used to predict the properties obtainable with similar resins.

Cure Characteristics

The cure characteristics of a typical HET-hexahydrophthalic system in Araldite 6020 are shown in *Figures 5 and 6*.

It is apparent that the final properties of the system, these properties being represented by its heat distortion temperature, are dependent upon the time and temperature of cure

† Trademark, Ciba Company, Inc.

** Trademark, Shell Chemical Corporation.
†† Dow Chemical Company

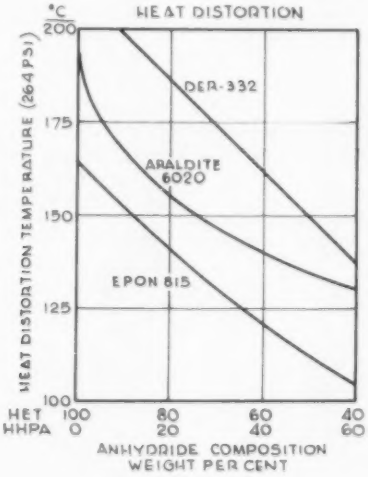


Figure 3

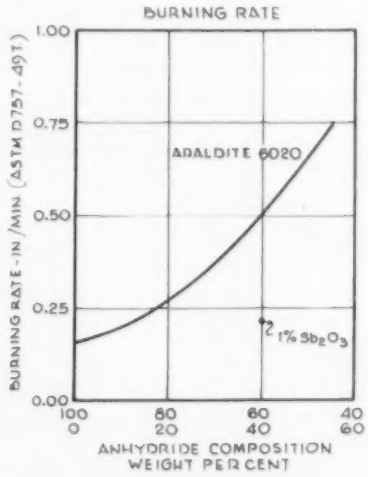


Figure 4

Figures 3 and 4. Characteristics of epoxy resin formulations with HET anhydride-hexahydrophthalic anhydride (1:1 anhydride-epoxy equivalence ratio) containing 0.5% catalyst (α-methylbenzyldimethylamine) (20 hour cure at 180°C.) Figure 3 gives heat distortion and Figure 4 burning rate.

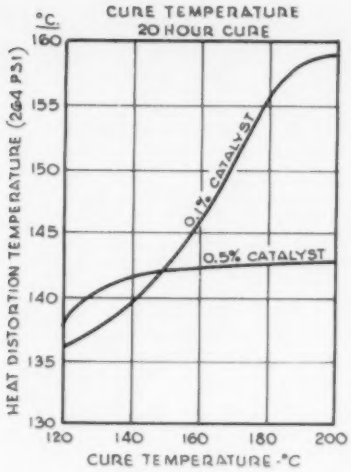


Figure 5

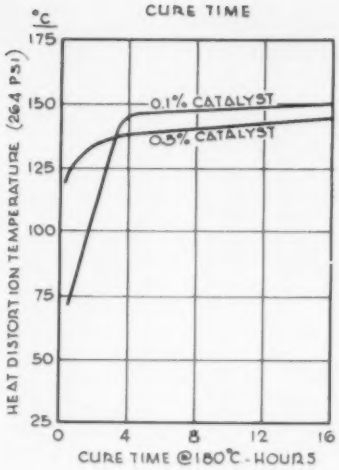


Figure 6

Figures 5 and 6. Cure characteristics of Araldite 6020 mixtures with a weight ratio of (60) HET anhydride-(40) hexahydrophthalic anhydride (1:1 anhydride—epoxy equivalence ratio) containing catalyst (α-methylbenzyldimethylamine). Figure 5 gives cure temperature (20 hour cure) and Figure 6 gives cure time.

as well as upon the catalyst concentration. Lower catalyst concentrations and higher cure temperatures generally yield higher heat distortion temperatures.

Handling Characteristics

An epoxy system must have a reasonable viscosity and an extended pot life in order to be useful. Its viscosity must be low enough to allow a typical plant operation, whether it be casting, encapsulating, laminating, or wet lay-up. Its pot life must also be such that the typical plant operation can be conducted without an excessive build-up of viscosity or the formation of premature gel.

Total Mix Method

The recommended method of preparing the mix is to fuse the coanhydrides and mix them into the resin which contains the catalyst.

The systems shown in *Figures 7, 8, and 9* demonstrate the effect of time upon the viscosity of a catalyzed HET-hexahydrophthalic mix in several different resins. The mixes were obtained by melting the coanhydrides at about 90°C and mixing them into the catalyzed resin which was at room temperature. The mix reached a temperature of about 50°C after which it cooled to room temperature in about three hours. The curves thus represent the combined effects of cooling and reaction upon the viscosity of the mixes. These effects will be somewhat dependent upon the size of the mix.

It is evident that the viscosity of a "total mix system" is greatly dependent upon the nature of the resin and the catalyst concentration. The viscosity build-up is more rapid with higher catalyst concentrations and with resins containing high hydroxyl values. The temperature history of the mix will also affect its time-viscosity relationship.

Masterbatch Method

The "masterbatching" of HET-coanhydride systems is useful to facilitate the handling of large quantities of a relatively fast mix, such as one containing Araldite 6020, which are to be used over prolonged periods of time. The method consists of preparing two liquid batches, one consisting of a portion of the resin which contains all of the coanhydrides and the other which consists of the remaining resin which contains all of the tertiary-amine catalyst. These two liquid batches are mixed as the demand requires, thus providing the following advantages over the "total mix" method:

Two component mixes are provided, each of which has a pot life of more than a normal eight-hour work day.

The component which contains the coanhydrides is devoid of catalyst, and the component which contains the catalyst is devoid of anhydride, thus providing relatively good storage characteristics for both mixtures.

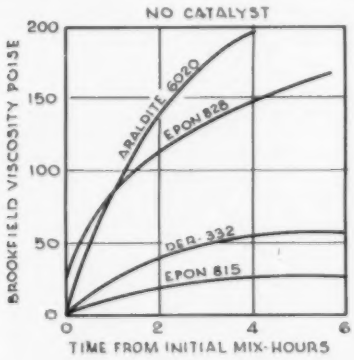


Figure 7

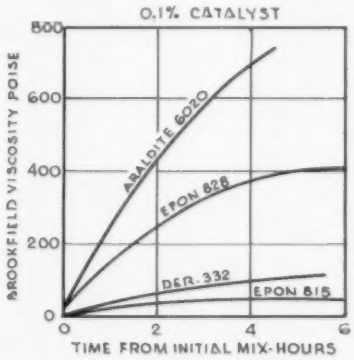


Figure 8

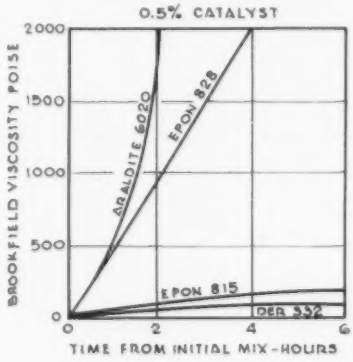


Figure 9

Figures 7, 8, and 9. Handling characteristics of "total mix" epoxy resin mixtures (varying catalyst concentration) with a weight ratio of (60) HET anhydride-(40) hexahydrophthalic anhydride (1:1 anhydride-epoxy equivalence ratio) catalyst (α-methylbenzyldimethylamine) (3 hr. cooling from 50°C. to 23°C.). Figure 7—no catalyst, Figure 8—0.1% catalyst, Figure 9—0.5% catalyst.

Table 2. Typical Properties of Araldite 6020 Castings with HET-Hexahydrophthalic Anhydride Formulations

Properties	ASTM Method	HET-Hexahydrophthalic[1]
Specific Gravity	—	1.360
Heat Distortion Temperature	D-648	143°C
Water Absorption (24 hr)—%	D-570	0.11
Fire Resistance	D-635	Self-Ext.
in./min.	D-757	0.52
Flexural Strength—psi	D-790	15,780
Flexural Modulus—psi	D-790	5.0×10^5
Tensile Strength—psi	D-638	12,620
Tensile Modulus—psi	D-638	5.0×10^5
Compressive Strength—psi	D-695	19,300
Hardness	Rockwell	M-113
	Barcol	34
Dielectric Strength—volts/mil (S/T)	D-149	371
(S/S)		372
Dielectric Breakdown—Kilovolts (S/T)	D-149	67
(S/S)		50
Dielectric Constant (1 MC) (Cond A)	D-149	3.15
(D 48/50)		3.20
Dissipation Factor (1 MC) (Cond A)	D-150	0.0137
(D 48/50)		0.0155
Volume Resistivity	D-257	10^{16}
Surface Resistivity	D-257	10^{15}
Insulation Resistance	D-257	10^{16}
Arc Resistance—sec.	D-495	13

[1] (60) HET-(40) hexahydrophthalic, 0.1% α-methylbenzyldimethylamine (calc. on total mix) 1:1 Anhydride-epoxy equivalence ratio. Cure for 6 hours at 180°C

The heating operation which is required to fuse the coanhydrides prior to mixing in the resin is necessary only at infrequent intervals.

The catalyst component is of sufficient volume to assure easy mixing into the coanhydride component, thus overcoming the problems which would be encountered in mixing a small amount of amine catalyst into a large quantity of the epoxy-coanhydride mix.

The storage characteristics of the two "masterbatch mixes" used for a (60) HET-(40) hexahydrophthalic system in Araldite 6020 are shown in *Figures 10, 11, and 12.*

Typical Applications

HET-coanhydride systems in epoxy resins have been found easily adapted to such general plastic operations as potting, encapsulation, wet lay-up, and matched metal die molding. Typical examples of these operations, using a (60) HET-(40) hexahydrophthalic system in Araldite 6020 are shown below:

- Casting or Encapsulation

The properties obtained from unfilled castings are listed in *Table 2.*

- Wet Lay-Up

a. Glass Mat

Two plys of 2 oz. glass mat were impregnated with the coanhydride mix at a temperature of about 40-50°C. The lay-up was enclosed in a cellophane envelope, placed on a glass plate, which was heated to about 80°C and worked free of air bubbles. The laminate was then pressed to 1/10 inch stops in an open platen press for one hour at 120°C.

The resulting laminate was of excellent appearance, contained about 28% glass by weight (ignition), and had a flexural strength of 28,000 psi, a flexural modulus of 1.3×10^6 psi, and a Barcol hardness of 45-50. Post curing of four hours at either 150°C or 180°C did not appreciably affect these properties.

b. Glass Cloth

Twelve plys of 181-Volan A* glass cloth were laid up parallel, and impregnated with the coanhydride mix at a temperature of 40-50°C. The lay-up was enclosed in a cellophane envelope, placed on a glass plate which was heated to about 80°C and worked free of air bubbles. The laminate was then pressed to 1/8 inch stops in an open platen press for one hour at 120°C.

The resulting laminates were of excellent appearance, contained about 58% glass by weight (ignition) and had the the following characteristics:

	Panel A	Panel B	Panel C
Press Temperature	110-120°C	110-120°C	180°C
Press Time, hours	1	1	4
Post Cure Temperature, °C	—	180°	—
Post Cure Time, hours	—	4	—
Flexural Strength, psi	66,900	71,700	78,800
Flexural Modulus, psi x 10^6	3.1	3.0	3.6
Hardness, Barcol	55-65	58-65	63-66

C. Matched Metal Die Molding

Excellent quality 1/10 inch laminates, containing about 46% glass by weight, can be obtained by matched metal die molding the HET-hexahydrophthalic mixture with four crossed plys of 1½ oz. OCF 219 mat.

Excellent release from steel dies was obtained by using a 1:3 solution of DC-20† in toluene.

The resulting laminates had the following characteristics:

Press Temperature, °C	170°C			150°C			
Catalyst Concentration, %	0.1	0.1	0.1	0.1	0.1	0.5	0.1
Press Time, Minutes	3	5	15	3	5	5	15
Flexural Strength, psi	25,500	28,600	40,400	Insufficient cure to remove panel from press.		42,400	38,900
Flexural Mod., psi x 10^6	1.27	1.44	1.77			1.82	1.64
180°F Torsional Mod.* psi x 10^6	Deformed	Deformed	Deformed			1.12	Deformed
Hardness, Barcol	24-32	26-42	45-55			46-54	41-54
Post Cure, 4 hr at 180°C							
180°F Torsional Mod. psi x 10^6	1.46	1.50	1.42			1.50	1.38
Hardness, Barcol	44-54	43-59	46-59			43-59	47-56

† Trademark, Dow Corning Corporation.

* This test is a modified version of ASTM D 1043-51 and has been briefly described by E. J. Premo, Proceedings SPI Conference, February 3-5 (1954).

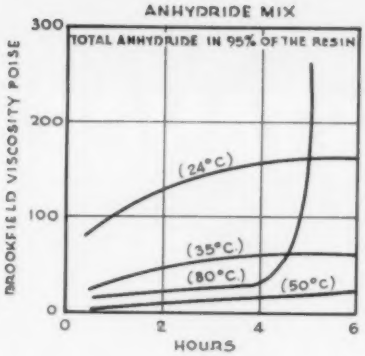


Figure 10

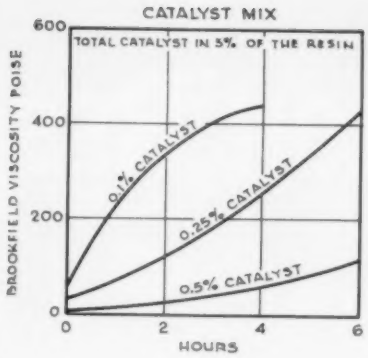


Figure 11

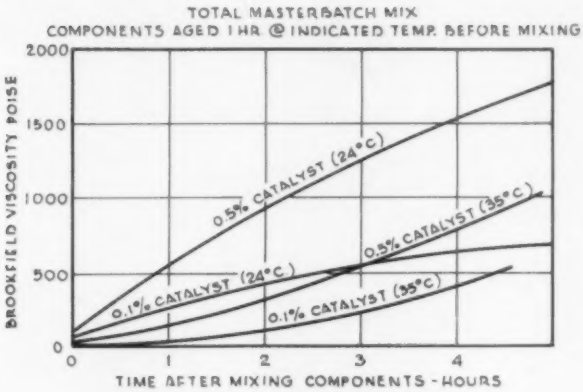


Figure 12

Figures 10, 11, and 12. Handling characteristics of "component masterbatch" Araldite 6020 mixtures with a weight ratio of (60) HET anhydride (40) hexahydrophthalic anhydride (1:1 anhydride-epoxy equivalence ratio) containing catalyst (α-methylbenzyldimethylamine). The "anhydride mix" (Figure 10) is prepared by combining the total coanhydrides, fusing at about 90°C, and dissolving the melt into 95 percent of the epoxy resin which is at room temperature. The "catalyst mix" (Figure 11) is prepared by mixing the total amine catalyst into 5 percent of the epoxy resin at room temperature.

It is evident that the viscosity of the "catalyst mix" increases as a function of time; however, this increase is relatively unimportant since the mix represents only a small portion of the total mixture which will be used.

The differences observed between the viscosities at various catalyst concentrations is mainly due to the dilution effect which the catalyst has upon the resin.

The "total masterbatch mix" (Figure 12) is prepared by mixing the components in a ratio of 0.24 parts by weight of the "catalyst mix" to 9.77 parts by weight of the "anhydride mix". These particular ratios hold only for the coanhydride system and epoxy resin used in this study. Other ratios need be calculated when different resins are used.

It is evident that the viscosity of the "total masterbatch mix" is a direct function of both time and catalyst concentration.

Sample Calculations

Calculations are presented which are illustrative of those which are necessary to compute the composition of typical coanhydride systems.

Resin: epoxy value 0.484/100 g.

HET-hexahydrophthalic ratio: 60/40 (weight ratio) — 1:1 anyhydride-epoxy equivalence ratio

Catalyst: 0.1% (calculated on total mix)

The epoxy value of a resin is usually provided by the manufacturer or can be calculated from the epoxy equivalence by the relationship:

$$\text{Epoxy Value} = \frac{1}{\text{epoxy equivalence}}$$

Molecular weight of HET anhydride = 371 thus 60 g.

$$\text{of HET} = \frac{60}{371} = 0.1617 \text{ equivalents}$$

Molecular weight of hexahydrophthalic anhydride = 154

$$\text{thus 40 g. of hexahydrophthalic} = \frac{40}{154} = 0.2597 \text{ equivalents}$$

Thus 100 g. of the 60/40 coanhydride mix will provide $0.1617 + 0.2597 = 0.4214$ equivalents of anhydride

Since the epoxy equivalence of the resin is 0.484/100 g. it indicates that 100 g. of the resin will require 60

$$\times \frac{0.484}{0.421} = 69.0 \text{ g. of HET anhydride and 40}$$

$$\times \frac{0.484}{0.421} = 46.0 \text{ g. of hexahydrophthalic anhydride}$$

to yield a total mix of 215 g. To this is added $215 \times 0.001 = 0.215$ g. of catalyst.

Conclusions

It is concluded that HET-coanhydride formulations, particularly HET-hexahydrophthalic systems, provide effective means for hardening epoxy resins. Through variations in the coanhydride ratios, a wide range of predictable properties can be obtained with systems which are easily workable.

Acknowledgment

The authors are indebted to Mr. P. Robitschek for his constructive suggestions relating to many sections of this work and to Mr. S. I. Raider who assisted in some of the determinations reported herein.

Literature References

1. Robitschek, P. and Nelson, S. J., *Ind. Eng. Chem. 48*, 1951 (1956).
2. Weiss, H. K., *Ind. Eng. Chem. 49*, 1089 (1957).
3. *Brit.* 795, 378, Ciba Co., August 8, 1954.
4. *Jones-Dabney Company*, File: Epi-Rez 507-4, September 20, 1956.

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Tensile Strength, psi	D 638	3,400
Elongation, %	D 638	45
Secant Modulus (Stiffness), psi	D 638	100,000
Hardness, Durometer "D"	D 676	60

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SOCIETY ACTION

Inter-Regional Membership Contest

Sherman M. Crawford,
Chairman, SPE Membership Committee

The April and May, 1960 issue of the SPE Journal gave you information on the 1960 International Section Membership Contest which started April 1 and will run to December 31, 1960. This contest will produce a Section grand membership champion. All sections will want to work hard for this.

Since there can only be one grand champion each year, to increase incentive and recognition, an inter-regional membership contest that will produce seven SPE regional champions has been added.

The inter-regional membership contest also started April 1 and will run until December 31, 1960. It will be governed under the same rules as the International championship contest. The first and second Sections in each Region as of June 30, 1960 are reported in the Table.

It is felt that such a contest will greatly increase local interest in membership growth. Akron, for example, competes more closely with Cleveland than with New York or Los Angeles. This by no means will detract from the International competition. No section will want to give up a chance to become the National grand champion of the entire society. It will be, rather, an added stimulus on a local scale. A Section taking its membership drive lightly will be far more likely to accelerate when it sees a chance to compete with members of a nearby group.

There will also be an inter-regional banner. The regional championship banner, which will be smaller in size than our International Banner, will be a "Traveling Banner" from Section to Section within the Region as the champion of that region may change from year to year. A new banner will be supplied after one Section in a region wins the banner three times. It would then become their permanent banner and a new regional banner will be supplied at that time.

Our membership goal for this year is 9,000 members in good-standing as set by our President, George Martin. Let's all go to work and show President Martin that his figure of 9,000 is too low. Help to bring a regional banner to your Section!

Leading Sections in SPE's Inter-Regional Membership Contest June 30, 1960

	SECTION	MEMBERSHIP* 3-31-60	APPLICATIONS REC'D SINCE 4-1-60	% INCREASE
		REGION I—NEW ENGLAND		
1.	Southern New England	159	17	10.7
2.	Connecticut	170	13	7.6
		REGION II—IROQUOIS		
1.	Ontario	205	17	8.3
2.	Quebec	114	8	7.0
		REGION III—MID-ATLANTIC		
1.	Baltimore-Washington	172	6	3.5
2.	Newark	751	22	2.9
		REGION IV—EAST CENTRAL		
1.	Cleveland	294	17	5.8
2.	Akron	187	10	5.3
		REGION V—SOUTHWEST		
1.	Florida	67	11	16.4
2.	Monterrey	29	4	13.8
		REGION VI—GREAT LAKES		
1.	Toledo	85	8	9.4
2.	Upper Midwest	159	8	5.0
		REGION VII—WESTERN		
1.	Rocky Mountain	33	5	15.1
2.	Pacific Northwest	60	3	5.0

*Sum of members-in-good-standing and members-in-process.

edited by
Thomas A. Bissell,
SPE Executive Secretary

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4P034	Graphite ½" by ½" fabric
4P038	Asbestos ½" fiber
4P042	High Flow Quartz
4P043	Long Fiber Quartz
4P048	"Refrasil" ½" by ½" fabric

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PAG Progress

Polymer Structure and Properties

Dr. Herman S. Kaufman, *Chairman PSPPAG*
Allied Chemical Corporation, Morristown, New Jersey

The almost breathtaking growth of the plastics industry, both scientifically and economically, has resulted in the availability of an unprecedented number of plastics materials, whose properties cover an ever widening spectrum, and are only awaiting the skill and imagination of the fabricator for proper utilization.

In order to achieve this, the modern plastics fabricator is obliged to understand and use such terms as molecular weight, molecular weight distribution, branching, rheology etc; terms which in the past were reserved for the long hair research scientists. A large part of the credit for this new sophistication must go to the material suppliers' technical sales staffs who have performed a much needed educational function. The realization that a more organized approach sponsored by SPE would be beneficial was in part responsible for the formation of the Polymer Structure and Properties Professional Activity Group, (PSPPAG) in 1959. At the first meeting the following scope of activities of the group was evolved:

1) To link polymer structure with process and product characteristics.
2) To educate process and product engineers with regard to polymer structure and properties.
3) To familiarize research personnel with processing and product design problems.
4) To assist in the organization of ANTECs and RETECs in the subject area.
5) To promote the presentation of a greater number of research papers at SPE meetings.

The PSPPAG Steering Committee formalized the objectives of the PAG as follows: "To advance knowledge and understanding of the structure of polymers, the properties of polymers and the relationship between structure and properties and to promote basic research in the field of polymers."

With the scope and objectives defined it becomes the task of the PAG to implement with practical action the noble sounding ideals. This phase is often quite difficult and is particularly so when there are no precedents to fall back on.

During the first year while the PAG was being organized under the chairmanship of Dr. R. Stromberg, the PAG assisted in the development of ANTEC programs and reviewed papers pertinent to the scope of the PAG. In this our second year we consider it essential that we adopt an aggressive program which would in an active way extend our area of usefulness.

To this end a meeting of the Executive Committee was held on June 16, 1960 in New York City. Fortunately the Committee was assisted in its deliberations by Mr. George Martin, our Society President, Mr. Frank Reynolds, the PAG Administrator, Mr. Thomas Bissell, the Executive Secretary of the Society and Mr. Lew Bernhard, Manager of the Administrative Department; all of whom attended the meeting.

It was clearly reiterated that the PSPPAG has a dual responsibility; a) to serve the bulk of the SPE membership by providing an educational link between polymer structure and properties, and fabrication and use and b) to provide up to date technical information to the members whose interests are in fundamental property and structure research areas.

With regard to the first responsibility it was proposed that a meeting or workshop be developed which would present the fundamentals of properties and structure in such a way that it would benefit the fabrication engineer. It is visualized that such a presentation would be truly educational and serve the membership at large in an important way. This proposal was unanimously accepted as being well worth the effort needed to plan and execute it. A sub-committee is working on details of program and section sponsorship. Written comments from the membership at large would be welcome. As for the second area of responsibility (to the research scientists) it was considered that for the immediate future this would be served by the 1961 ANTEC symposia on basic polymer research which are being set up in cooperation with the PAG. For the future, it is planned that a RETEC on a timely research topic will be arranged.

The officers and committee are vividly aware that the PAG must perform active useful functions or it has no real reason for existence. It is the sincere hope that the planned efforts will be brought to successful culmination.

—■—

edited by
Frank W. Reynolds, *PAG Administrator*
(International Business Machines Corp.)

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PLASTICS AROUND THE WORLD

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Alexander Baczewski: (L'Officiel des Matières and Pensez Plastiques—Mar. '60)
R. George Hochschild: (Pensez Plastiques—Feb. '60, Der Plastverarbeiter, Kunststoffe and Plaste Und Kautschuk)
Geza Gruenwald: (Kunststoff-Rundschau)
Alfred Alk: (Materie Plastiche and Poliplasti)
Joseph B. Wolheim: (Tworzywa-Guma Lakiery)

FRANCE

INDUSTRIE DES PLASTIQUES MODERNES

APRIL 1960

Report on Symposium about Plastics in Agriculture

Le Gloru and Cano discuss the various aspects of using plastic film for the purpose of shortening the growth cycle. M. Brun describes the results of using plastic shelters in the cultivation of melons while M. Bellet investigates the techniques and economics of applications of plastics in agriculture in general. Ersu and Martineau report on the use of plastic films in special regions while Pr. Chouard discusses the means of saving water in cultivating the Sahara by underground irrigation. M. Marcellin describes methods of plastic packaging of fruit for improving preservation at room temperatures.

L'OFFICIEL DES MATIERES

MAY 1960

Phenol Formaldehyde Resins—pp. 381-390

The third installment on the construction of a small resin plant brings calculations for heat transfer and agitation. A drawing of a resin kettle is included.

Non-supported Films—pp 391-398

Protein films are manufactured by 1. purifying casein or soy bean protein, 2. dissolving either one in alcoholic sodium carbonate 3. coagulating with formaldehyde or tannin. The author claims this to be common American practice. A detailed description of the manufacture of nitrocellulose films follows (drawings) Such films are cast upon gelatine coated copper foils a method which prevents corrosion of the metal and guarantees a smooth surface. (40 references)

The Forming of Hollow Objects—pp 399-404

Centrifugal molding, various methods used in the forming of plastisols and the blow molding of plexiglas are treated. (illustrations, 34 references)

PENSEZ PLASTIQUES

FEBRUARY 1960

Phenocolor—pp 17-20

The thermoplastic industry likes to talk about the upgrading of its products. However, this is one of the problems where a final solution has not yet been achieved but every day finds the industry one step nearer its final goal. Plasticizers have had a major share in providing better and more useful plastics. Chlorinated diphenyls and chlorinated paraffins offer some definite advantages to the plastic producer, and the article describes in detail the properties of these classes of compounds and their effects on a number of resins.

The Use of Radiation in the Plastics Industry (Part 1)—(author—G. Duglas)

This is the first part of a series on the above subject. The author first discusses the various aspects of nuclear physics as they pertain to irradiation, and then treats in detail the effects of irradiation on plastics. The physical and chemical changes brought thus about in polycarbonates, polyethylenes of both high and low density, terephthalates, fluorocarbons, polyvinyl chlorides and polystyrene are mentioned in detail and documented with tabular data. Radioactive isotopes and their formation are then discussed in detail.

The series promises to be of prime interest to members of the plastic industry.

MARCH 1960

The Use of Radiation in the Plastics Industry (Part 2)—(author—G. Duglas)

Following a treatise on isotopes and the generation of accelerated particles, French and Russian progress in the field of graft polymerisation is described.

GERMANY

DER PLASTVERARBEITER

APRIL 1960

Properties and Molding of Polypropylene (Part 2)—pp 161-170)

This paper concludes an article given in the previous issue of this journal. It discusses the properties and the molding conditions necessary to mold the isotatic polypropylene of the Farbwerke Hoechst AG, Hostalen PP. Items discussed are moldability, effect of molding conditions on the shrinkage of the molded parts, post-shrinkage of the molded parts, molding temperature and the effect of molding conditions on the mechanical properties of the plastic parts. It further discusses in detail the post-working of the parts such as gluing, fusing, annealing and mechanical working of the molded parts such as, for example, sawing, drilling and polishing.

KUNSTSTOFFE

MARCH 1960

Explanation of Strength Decrease of Heat Sealed Plastic Sheeting —p 148

In order to be able to state quantitatively the strength of sealed seams, the following factors must be strictly controlled: Temperature, pressure and duration of sealing. The tear test must be contrived so that it is foolproof and reproducible. The object of this paper is to determine the causes of failure of sealed seams in practice.

Instrument for Measuring the Permeability of Plastics Sheeting to Moist Gases—p. 156

The authors first of all discuss the methods of measuring gas permeability of plastics sheeting available today, and consider how these methods could be used for measuring the permeability of moist gases. They then describe a new instrument which can be used for measuring the gas permeability of plastics film and sheeting as well as coated papers if the relative humidity of the test gas is known. General conditions, accuracy of the values obtained and potential applications of this method are described.

Injection Molding Tool for Small Wheels—p. 197

Using an example from actual practice, the authors discuss the various factors that have to be taken into consideration in designing a tool for moulding Nylon gear wheels. The galvanic method is recommended for inserts.

APRIL 1960

Properties, Chemical Composition and Crystallinity of Polyamide Plastics—p. 203

Among the many thermoplastics which have reached considerable importance during the last few years, the Polyamides have proved valuable materials for the production of mouldings by extrusion and injection moulding. Many different types of polyamide have been made possible by modern chemistry. The present paper discusses their origin and properties in relation to structure, crystallinity, temperature, time, moisture content and other factors.

Two New Machines for the Production of Deep Drawn Plastics Packages—p. 219

Two new machines are described which were developed for the production—on a continuous and rational Basis—of three dimensional, semi-rigid packages, drinking cups and similar articles.

MAY 1960

Dynamic Behaviour of Rigid PVC p. 277

By means of rotary flexing tests carried out on rigid PVC rods over a temperature range of 30 to 50°C., its creep strength was determined by Wöhler curves. Utilizing the temperature increase within the rods caused by repeated flexing, the internal damping of the material was determined. Examination of the fractured surfaces enables certain conclusions to be drawn regarding the fracture mechanism.

Glass Fibre Reinforced Plastics in Car Body Construction—p. 284

An investigation into the potentialities of glass fibre reinforced plastics in car body construction is presented in this article. A comparison between the properties of these materials with those of steel shows that insufficient is known as yet about the creep or long-term behavior of glass fibre reinforced plastics, their examination and evaluation. The material available on this subject is critically examined and discussed and new comments and ideas suggested. The problems of surface finishing and of the behavior of the surface will be discussed in a second part of of this paper, to be published at a later date.

KUNSTSTOFF-RUNDSCHAU

MAY 1960

Decorative Plastic Coatings Made by the Fluidized Bed Process— (author—Erwin Gemmer)

The author, the inventor of the fluidized bed coating process (in this country U. S. 2,844,489), describes methods for producing lustrous decorative coatings on metals and also their properties. Originally only corrosion resistant coatings were applied by this method. Now a celluloseacetobutyrate resin and plasticized polyvinylchloride resins are available in the desired granular structure (less than 200 microns) in any color. The preheating temperature for the parts is approximately 350°C. Many practical aspects are discussed at length, e.g. cleaning, primers, elimination

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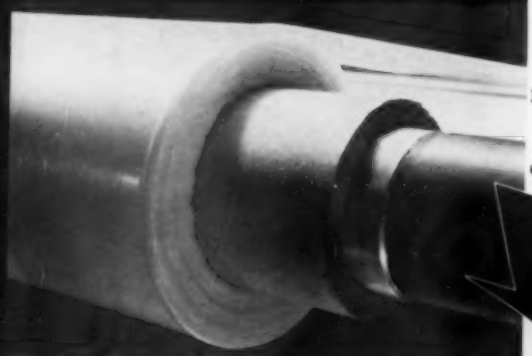

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of crazing on acetobutyrates, checking permissible thermal degradation, and patching spots where the part was fastened for dipping.

Corona Resistance of Insulation Materials—(author—H. Suhr)

The "true" dielectric strength of an insulation material is seldom measured and is of no practical value since the corona starting voltage is usually much lower. Primary corona reaction products, like ozone and nitrogen oxides react with the insulation material destroying it after a certain time. Graphs show the time dependence of the dielectric strength of some important insulation films, leveling off when the stresses reach the corona starting voltage. Three methods for measuring corona resistance are described and a not too reliable listing ranks the purely organic insulation films between the worst corona resistant, teflon and the best, polycarbonates.

PLASTE UND KAUTSCHUK

MARCH 1960

Measurement of Compressibility of High Polymers as a Function of Pressure—pp 128-131

The linear compressibility of high polymers as a function of hydrostatic pressure is determined within the range of 50 to 4,500 kp/cm^2 at room temperature. The change of length of the test specimen produced by the pressure is determined by a change of capacity. The investigation includes a polyamide resin, a polytrifluorchlorethylene plastic, an epoxy resin, polymethyl methacrylate, polystyrene, polyvinyl chloride and cellulose acetate.

Current Status of Standardization in the Plastics Field—pp 113-117

The article starts with a statement of conclusions regarding different properties of a number of plastics and it expresses the need to standardize the properties of these plastics. The paper then continues with a description on the development and current status of the standardizations of these plastics. As is shown by the example of a systematic standardization of laminated plastics, all stages of the production of plastics should be described by standards so that a uniform material may be made.

The example of PVC is given to show how to realize a systematic standardization plan. The article includes a list of main offices of plastics standardization agencies in the German Democratic Republic, discusses problems to be solved from 1960 to 1965, and concludes with a consideration of conditions necessary for a future productive standardization program.

APRIL 1960

Contributions to the Analytical Chemistry of Plastics (Part XI. Determination of Processing Aids (Plasticizers) in the Manufacture of Cellulose Hydrate Films)—pp 167-168

A description is given of the permanganometric determination of oxide wax A in pure aqueous solution and in aqueous glycerine solutions. It is followed by the (qualitative and quantitative) determination of the glycerine and oxide wax A content in cellulose hydrate films. The paper concludes by describing the determination of the composition of plasticizers in cellulose hydrate.

Plastics in Room Furniture—pp 179-181

A number of uses of plastics are suggested for the furniture industry and the home architect. The article contains two tables which show further details on the use of plastics in the furniture industry. Another table shows the mechanical properties of veneers and furniture lumber and compares it with plastic laminates, polyethylene and polyvinyl chloride. The article further contains 8 drawings to illustrate the use of plastics in the home.

ITALY

MATERIE PLASTICHE

APRIL 1960

The "Celuang," Constructed Entirely with Reinforced Plastics Structural Elements—pp 307-313

The "Celuang" is a 50 ft. luxury motor cruiser completely fabricated from glass reinforced polyester. The outer skin was prepared by hand layup on a standard wooden mockup to a thickness of about ⅝". Inside this skin was applied a net of reinforced members about ½" thick which when covered with an interior ¼" facing of more glass, divided the hull into around 400 isolated compartments. The hull is unsinkable and insulated. The article describes and illustrates with colored photographs the Celuang and some of its construction details.

The Mechanisms of Aging of PVC Under the Action of Light and Heat—pp 314-318

The authors analyze the concepts of stability to light and heat which are currently accepted. They then examine some of the mechanics of degradation, illustrating the most notable in the light of current knowledge.

Molding Polyethylene for Extrusion and Blowing—pp 319-323

The physical properties of blown bottles made from two Italian polyethylene resins are herein presented. The article discusses the technology of blowing and gives practical directions for obtaining best results which are applicable to any resin in any blowing apparatus.

Montivel In the Photomechanical Industry—pp 324-325

Photoreproduction is made less costly, precision is increased, and storage requirements are substantially reduced by means of Montivel, a transparent ethyleneglycol terephthallate film. The sensitized Montivel is mounted on rigid acrylic or glass, exposed and developed normally, and then separated from its heavy backing with water.

Auxiliary Products for Polymethylmethacrylate—pp 326-332

In adopting newer techniques of extrusion to methacrylate production, the manufacturer should take advantage of the commercial development of processing aids and raw materials used in production. Anti-static agents, colorants, luminescent pigments, opalescent pigments and how to mix; adhesives, their use with methacrylate and other materials; inks and surface coatings; and lubricants are headings in the body of the article.

Plastic Syringes—pp 365-369

Hypodermic syringes of various plastics and in various packages are described and illustrated. Included are prefilled and presterilized units ready for use as well as individual components.

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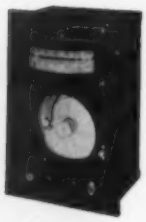

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POLIPLASTI

MARCH-APRIL 1960

Practical Experience With Plastic Piping in the Low Countries—pp 18-26

Plastic piping has increased because: some solids are very destructive to metals; the countries have small resources of metals; the generally flat nature of the terrain does not require more than moderate pressure for operation; distribution of coke oven and natural gases are increasing; electrical conductors must be enclosed in conduit; the organizations distributing water, gas and electricity reached early agreement on quality standards which have given the industry impetus and have increased the public's confidence. The author discusses common methods of joining lengths of pipe and of adding service branches. Under the heading of Practical Experience are several pages of problems which have arisen and the means adopted to overcome them. This article deserves wider distribution because of its practicality in a new field. 6 References.

Dialux Resins-New Transparent Vinyl-Ester Polymers—pp 13-17

This is a report of work by LIRC to develop Dialux copolymers of itaconic acid esters, particularly the methyl ester with polystyrene. Itaconates are transparent, but fragile. Co-polymerization with styrene yields clear, tough resins with softening points above 100°C and other good physical properties. Tables, graphs and illustrations.

New Data on Heatsealable Films—pp 33-39

The article describes laboratory apparatus for the controlled sealing of films by impulse or heat, and presents graphs, charts and tables to illustrate results of experimental work.

POLAND

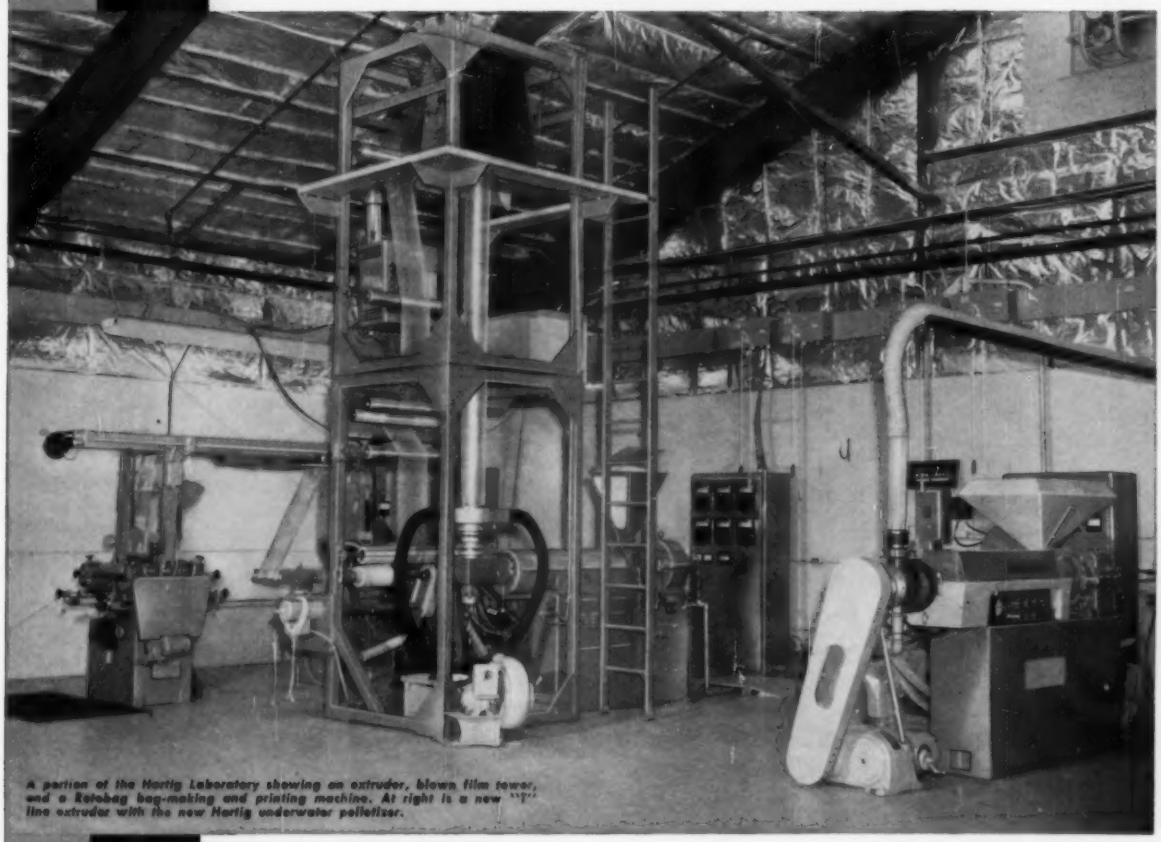
TWORZYWA-GUMA LAKIERY

JANUARY-FEBRUARY 1960

Plastic Materials in Contact with Food—(author—Stanislaw Homorowski)

This article publishes a detailed list of materials approved by the Food and Drug Administration (U.S.A.) for the use in food packaging. The author also quotes the German regulations regarding the use of plastic materials in contact with food.

the Hartig Laboratory is your laboratory for pre-production testing of extrusion processes and equipment . . .



A portion of the Hartig Laboratory showing an extruder, blown film tower, and a Rotobag bag-making and printing machine. At right is a new [illegible] line extruder with the new Hartig underwater pelletizer.

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104 Prentiss St., Munroe Falls, Ohio
Ph—Overdale 8-5731

New England ..... R. D. Sackett
Circle Drive, East Long Meadow, Mass.
Ph—Laurel 5-3853

Metropolitan N. Y. C. ..... Jim Ferrier
Box 531, Westfield, N. J.
Ph—Adams 2-9390

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HE-660

ABOUT MEMBERS

Mr. Prideaux

Donald G. Prideaux has been promoted to manager of Rezolin's (Inc.) Eastern Division. His headquarters will be Newark, N. J.

Kenneth G. Michel has been appointed Vice President and Assistant General Manager of the Bradley-Sun Division of American Can Co. His headquarters is Maynard, Mass.

Frank W. Reinhart, Chief of the Plastics Section of The National Bureau of Standards, gave the Academic Exercise Address of the Special Courses Division at the Newark College of Engineering on June 29. Title of Dr. Reinhart's address was Levels of Scientific Education. Dr. Reinhart is Chairman of the Society of Plastics Engineers Editorial Advisory Board and is also a member of the Publications Committee. He is also a Past President of the Society.

C. H. Strong has been appointed a Special Representative of Union Carbide Plastics Co., Milwaukee, Wisc.

Guy Phelps Dodge, President of Phelps Manufacturing Co. of Westport, Conn. has sold control of his company to Heli-Coil Corp. of Danbury, Conn.

Ralph E. James, Jr., Vice President of The Polymer Corp., Reading, Pa. was elected to the corporation Board of Directors at their meeting this past June, it was announced by **Louis L. Stott,** Polymer President.

Robert W. Ward is President of the newly organized Olympic Chemical Co., Greensboro, N. C., producers of polyurethane foam. Mr. Ward has announced the appointment of **Lester W. Bates** as plant manager.

Harry Raech, Jr. has been named Western Regional Manager of Food Machinery and Chemical Corporation's Dapon Dept. He will be responsible for the marketing of FMC's diallyl phthalate molding resins and laminates in 11 Western states.

Mr. Reed

John J. Reed has been appointed Executive Vice-President of Casavan Industries, Inc., Paterson, N.J. Mr. Reed was formerly Manager of Market Development, Allied Chemical's National Aniline Division.

Oscar Daffren retires from Como Plastics, Columbus, Ind. He was one of the founders of the company and has spent 22 years in the injection molding industry. Mr. Daffren's duties will be assumed by **James P. Reeves,** who has been elected a director and Vice President of Sales and Market Development.

Mr. Reeves

John L. MacAdams, formerly of the Semet-Solvay Division of Allied Chemical Corp., has joined the Applied Research Branch of the Research and Development Division of the Carborundum Co. as a chemist in the polymer program.

C. Howard Adams, manager of plastic development for Monsanto Chemical Company's Research & Engineering Division development department at St. Louis, will return to the company's Plastics Division at Springfield, Mass. as a senior engineering supervisor in the product engineering group.

John A. Helgesen joins Marbon Chemical, Division of Borg-Warner, as product applications engineer. Mr. Helgesen formerly was with Baxter Co. for 9 years and is a graduate of the University of Cincinnati.

Dr. Donald M. Knott has recently been promoted to manager of industrial chemical development for the Chemical Sales Division of Chas. Pfizer & Co., Inc. Dr. Knott has B.S. and Ph.D degrees from the Massachusetts Institute of Technology.

Costas H. Basdekis moves up as assistant research director for polystyrene in Monsanto Chemical Company's Plastics Division at Springfield, Mass., after serving as a senior group leader in research. Also for Monsanto, **Leo P. Paradis** has been appointed group leader of the polystyrene product development group.

John M. Avery joins Marbon Chemical as a technical sales representative in the Indiana area.

Samuel Ringel heads up a group of sales-engineers as Marketing Manager, Epoxy Products Div. of Joseph Waldman & Sons, Irvington, N.J. He is a graduate of Polytechnic Institute and Boston University.

Mr. Ringel

H. Martin Allard is now Vice President—Plastics, for Improved Machinery, Inc., Nashua, N. H. Mr. Allard has been with Impco for 25 years.

Mr. Allard

The Kordite Co., Division of National Distillers and Chemical Corp. has named **Melvin S. Cagen** Plant Technical Superintendent at Macedon, N. Y. Mr. Cagen was previously associated with Olin-Mathieson and Heyden Chemical Corp.

Mr. Cagen

George H. Reed, has been elected Chairman of the Thermoplastic Pipe Division, SPI, **John Lainson** was elected Vice-Chairman of that Division. **George C. Anderson** was elected Chairman of the Plastic Pipe Research Council.

Richard G. Hayes has been named to the newly created post of technical consultant on urethanes, the Dayco Corp. Mr. Hayes will develop special formulations and provide customer assistance for the various sales departments handling urethanes. He is a graduate in chemistry from UCLA.

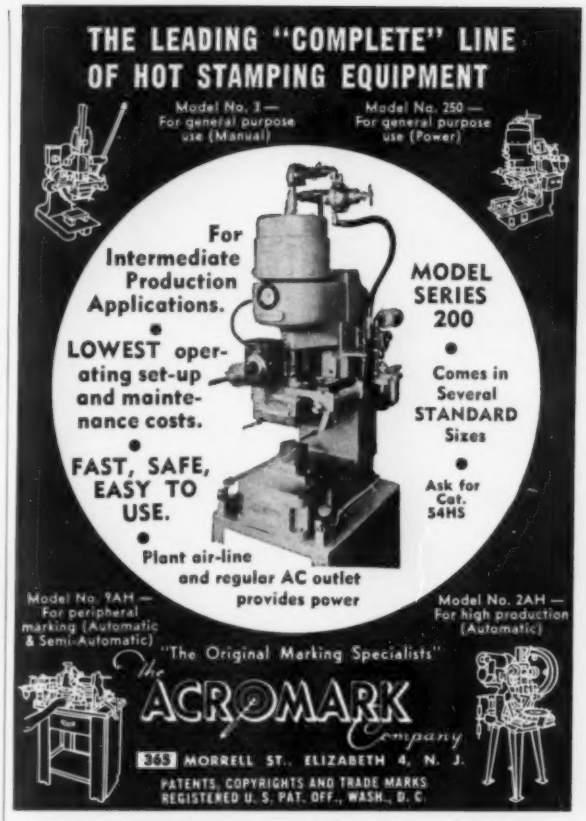
Woodrow J. Vogel has been promoted to general manager of the newly formed Plastics Division, Reynolds Metals Co., Grottoes, Va. He was formerly general market manager for plastics.

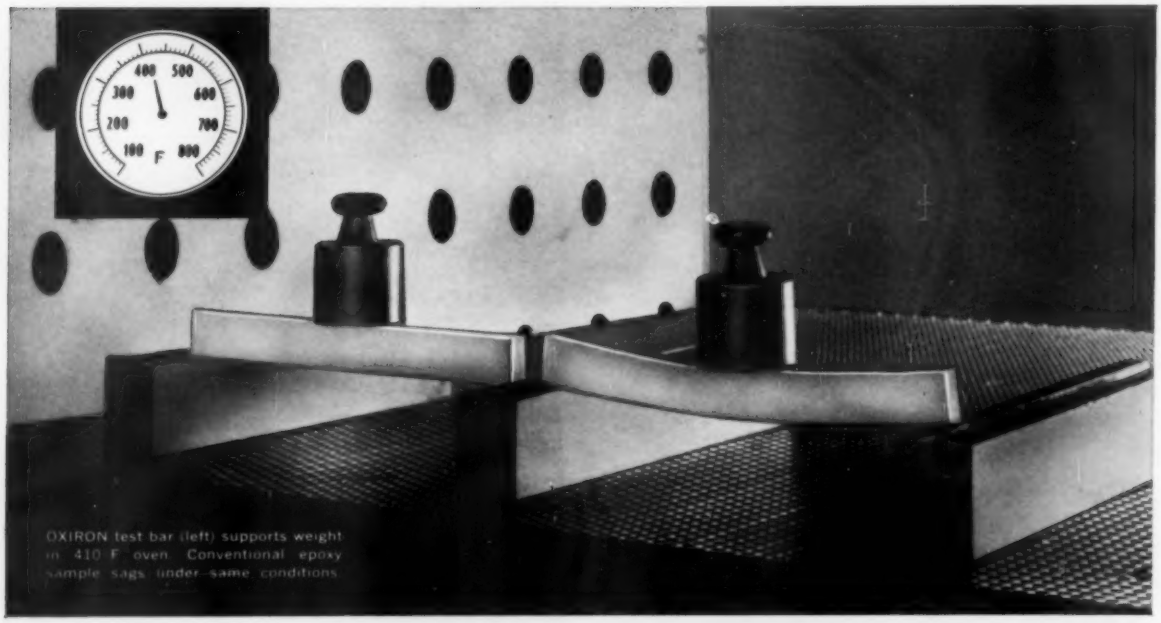
Harold W. Lenheiser has been appointed executive sales engineer for Detroit Plastic Products Co., Mt. Clemens, Mich. He has been associated in the past with Wolverine Plastics.

David A. Daniels, for the last 4 years with Convair, in Fort Worth, has been appointed to the Dallas Sales Office, Coast Manufacturing and Supply Co., Livermore, Calif.

Paul E. Doucette joins the research and develpoment staff of Hysol Corp., Olean, N. Y. He will be responsible for Hysol's product development program on molding and pelletizing powders.

Leonard W. Knell has been appointed Sales Manager of Varcum Chemical Corp. (Canada) Ltd., Varcum is a wholly-owned subsidiary of Reichhold Chemicals (Canada) Ltd.





OXIRON test bar (left) supports weight in 410 F oven. Conventional epoxy sample sags under same conditions.

NEW OXIRON EPOXY RESINS OFFER UNUSUAL HIGH TEMPERATURE PROPERTIES

Even after long exposure at elevated temperatures, OXIRON resins have high flex strength and show little weight loss. Anhydride-peroxide-cured OXIRONS resist deformation over a broad range of temperatures. The gentle rise of their heat distortion curves demonstrates why these resins are acceptable for practical use at temperatures far above the heat distortion point (see diagram). In addition to high-temperature strength, OXIRONS have excellent electrical properties which they retain over a wide range of temperatures, show superior resistance to creep at elevated temperatures.

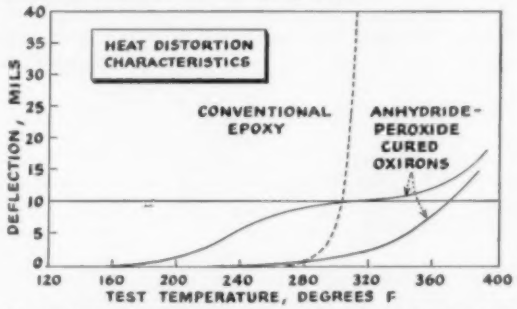
OXIRON resins are unique as epoxies, because they are epoxidized polyolefins rather than bisphenol-epichlorohydrin-type reaction products. Since they provide *10 or more* reaction sites per "monomer" unit, they have a remarkable degree of chemical versatility, as their cure reactions show. The resins are available in a wide range of viscosities and offer an unusual combination of advantages:

Novel Cure: OXIRONS can be cured through their reactive double bonds as well as epoxy and hydroxyl groups. They are the only epoxy resins that can be cured with peroxides. However, conventional epoxy curing agents may also be used. OXIRONS have high reactivity with anhydrides and dibasic acids at low temperatures . . . provide increased pot life with polyamines . . . react with a variety of other curing agents such as polyphenols, Lewis-type catalysts, polysulfides.

Economy: Low-cost curing agents may be used in high proportions.

Low Density: 20% lighter than ordinary epoxies—cured resins likewise have lower density.

Outstanding Chemical and Electrical Resistance: Excellent resistance to alkalis, acids and solvents—cured resins have good electrical properties.



This graph shows that—unlike conventional epoxy resins—the heat distortion curve of OXIRONS does not break sharply with temperatures . . . can be used above the heat distortion point itself.

Send for our Epoxy Data Booklet which describes OXIRON *2000, 2001, and 2002 in detail, contains curing information and gives suggested uses. If you'd like a sample, let us know what application you have in mind so that we can supply a suitable resin.*

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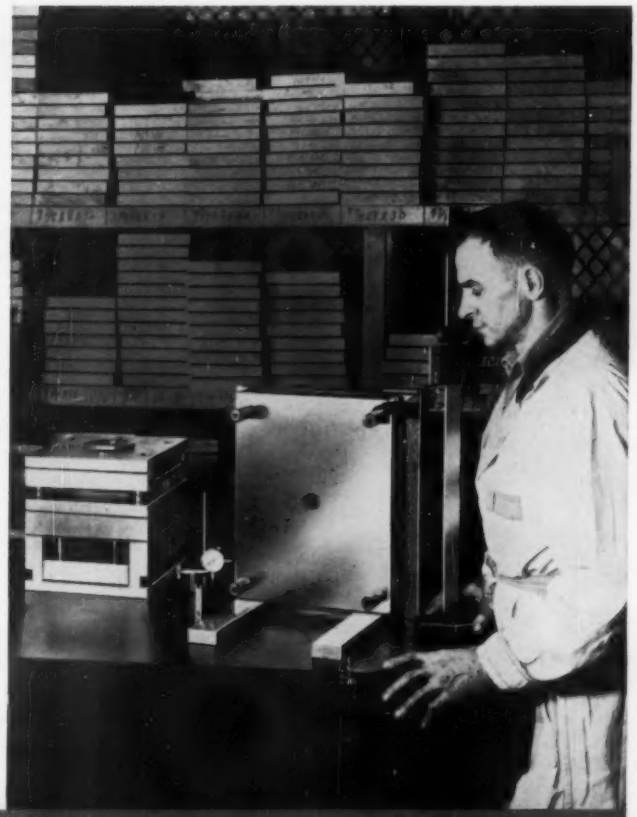

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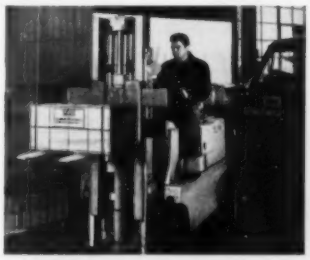

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I want to thank you for your past considerations, and assure you that we will make every effort to merit your continued patronage.

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We are planning on the expansion of our facilities in the extrusion and calendering fields; and an aggressive program of color development and improved deliveries will be undertaken in the block sheet division.

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Arizona... SPE's Newest Section

SECTION NEWS

Arizona

President Martin Presents Charter to Arizona Section

More than 50 members and guests traveled over 60 miles on June 8 to see President George W. Martin, formally present the Charter to SPE's newest Section, and to hear talks by President Martin and Executive Secretary, Thomas A. Bissell. Granting of a Section Charter to Arizona by Council at its May 16 meeting brought the total of SPE Sections to 45.

The meeting was held at the Casa Grande Country Club, Casa Grande, Arizona, the "half-way" stop between Phoenix and Tucson, in which cities virtually all of the forty odd members affiliated with the Arizona Section live and work.

Stressing the necessity for SPE's international Society and its Sections to work together to help each other attain the Society's objective, Martin said: "Your Officers are SPE members, just as you are, who temporarily by virtue of elected office are responsible for the continuity and progress of what is growing to be a tremendously large Society."

Stating that the primary goal of his administration was "to make 1960 a PAG year", Mr. Martin concluded by outlining the opportunities offered by PAGs and PACs to individual members to increase their professional stature and the potential benefits of their participation to the Society and the industry.

In a brief preliminary talk, Executive Secretary Bissell reviewed the services available to individual members and to Sections from the Executive Office and staff. "The main function of our office and staff", he said, "is to relieve members of administrative detail so that they can concentrate their efforts on the technical activities of the Society."

Officers of the Arizona Section are:

President
Samuel Windman
Phoenix Plastics
1423 S. 28th Street
Phoenix, Arizona

Vice President
Ted W. Kerr
Arizona Plastics Extrusion Co.
1347 N. 22nd Avenue
Phoenix, Arizona

Secretary
Don H. White
University of Arizona
Applied Research Lab.
Tucson, Arizona

Treasurer
Alan C. Bennett
Goodyear Aircraft Corp.
Litchfield Park, Arizona

Councilman
Thomas Q. McCloskey
Goodyear Aircraft Corp.
Litchfield Park, Arizona

Akron, Ohio

Rigid Vinyls

GEORGE REESMAN

Mr. Robert P. Hopkins of the Rohm and Haas Co. presented a very interesting talk entitled "Rigid Vinyl Modified with Acrylic Polymers" before the Akron Section on Friday evening, June 4.

Mr. Hopkins had presented a related paper at the SPE meeting in Chicago which was subsequently published by the SPE Journal in March, 1960. This particular talk included new information obtained since the original paper was written.

Test data was presented to show that 10% acrylic polymer could be added to vinyl homopolymers, resulting in improved processing, no change in physical properties, very little change in chemical properties

Arizona Section President Sam Windman accepting Charter from SPE President George W. Martin.

Thomas A. Bissell, SPE Executive Secretary, addresses members of the newly chartered Arizona Section. Pictured, left to right are: Don H. White, Secretary, of the University of Arizona, President George W. Martin, Bissell, and Ted Kerr, Section Vice President, Arizona Plastics Extrusion Co.

Central Indiana Section members have fun at golf tourney. Pictured left to right, are: Jack Efflin, Delco-Remy Division, Chairman of the tourney; Milton Brummer, Rohm & Haas Co., President of the Section; Eugene Quear, Delco-Remy Division; Gene O'Mahoney, RCA, program chairman; and John Mulhern, Union Carbide, social chairman. Mr. Quear is a member of SPE's Publications Committee, and was Chairman of that Committee during 1959. Mr. Brummer is a past member of the Publications Committee.

and a substantial lowering of the brittle break-point.

Section Officers wish to thank all the individuals and organizations whose efforts and contributions made the May 20 Golf Outing such a success. 128 members and guests enjoyed golf, and 135 came for dinner. Congratulations to B. Schulenberg for low gross score and to Ed. McClellan for his hole-in-one.

Buffalo

Ladies Night at Buffalo

ANDREW J. HAMMERL

The Annual Ladies Night of the Buffalo Section was held on May 28th at the Williamsville Inn, Williamsville, New York. A short talk was given by William Dunmeyer, President of the Buffalo Section after which prizes were awarded to all of the ladies present.

Central Indiana

Golf Tourney

D. E. COLLINS

The Central Indiana Section conducted its annual golf tourney-outing on June 4th, at the Anderson Country Club. A record attendance of 105 members and guests enjoyed the event.

New York

Polystyrene Fillers

"Wollastonite* can lower raw material cost of polystyrene compounds anywhere from 6-10%—at concentrations of from 20-30%—without impairment of the physical properties of those compounds," reported Peter Virtue of Godfrey L. Cabot, Inc., Minerals & Chemicals Division, in a talk at the May meeting of the Injection Molding Subsection of the New York Section of the Society of Plastics Engineers.

* Godfrey L. Cabot's trademark Cab-o-lite®.

He pointed out that despite previous attempts of the industry to find a suitable filler or extender in polystyrene, until now, all have failed. He presented data and slides to show that now, for the first time, polystyrene molders can realize the economy of extender use to provide substantial finished product money savings. And he also pointed out that there is essentially no additional processing or processing expense necessary for incorporation of the Wollastonite into the product.

North Texas

Thermoforming Techniques

ERNEST DOURLET

Robert E. Kostur, Sales Manager of Comet Industries, Franklin Park, Ill., spoke before the June 20th meeting of the North Texas Section, SPE. He presented a very interesting program entitled: "Summary of Thermoforming Techniques". After a brief history of thermoforming Mr. Kostur showed slides illustrating various methods and techniques used in the fabrication of sheet plastics. He also discussed the advantages and disadvantages of thermoforming plastic parts as compared to injection molding.

Rochester

Rochester Enjoys Cruise

DAVID L. MESSENGER

On Saturday, May 21st the Rochester Sections Annual Spring Cruise and Ladies Night was held at the Rochester Yacht Club. Over two hundred members and guests were present.

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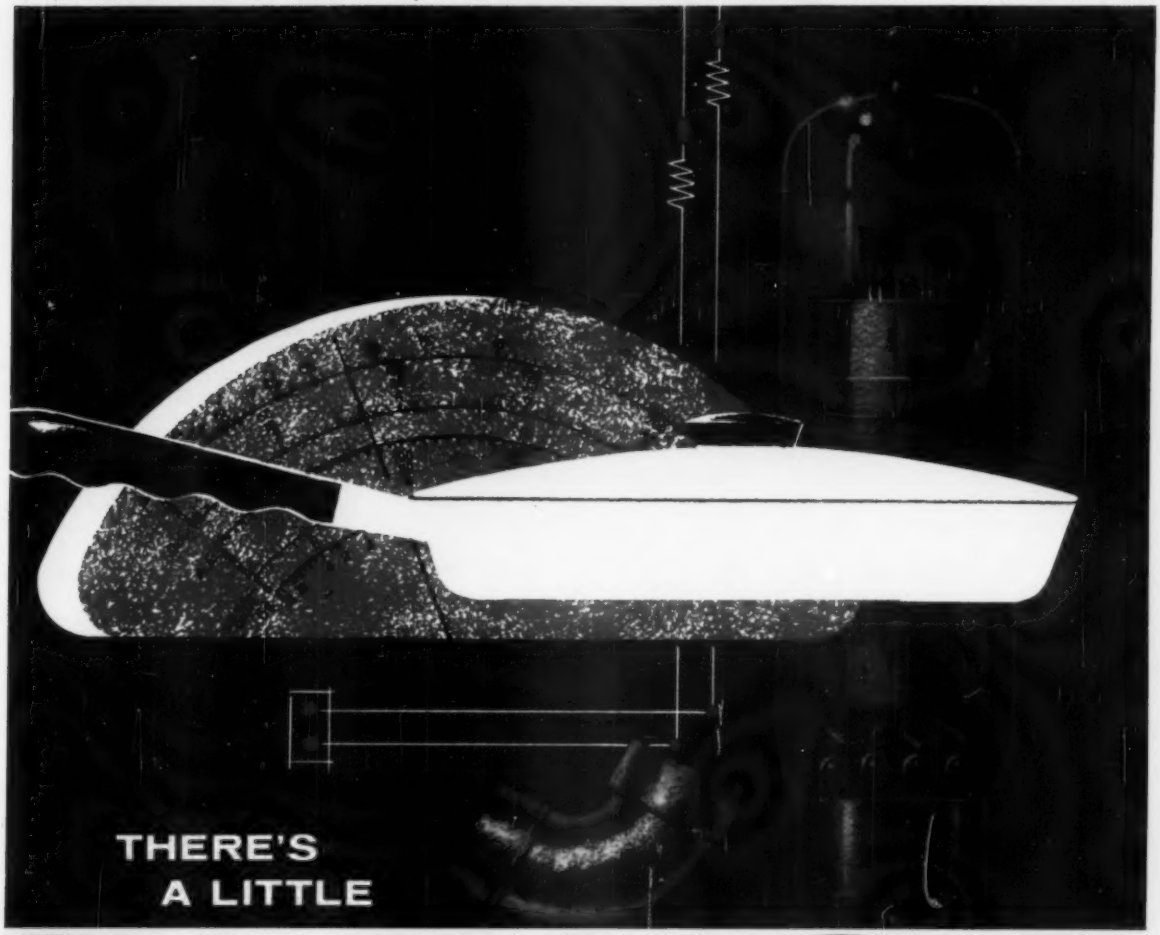

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. . . AND THE BEST OF COMPANIES PUT IT THERE. From the most delicate of subminiature switches to the toughest of subterannean pipe fittings . . . *Plenco phenolic molding compounds* are key ingredients in the production plans of major manufacturers across the country. Large or small, industrial or consumer, *your* company and product can benefit from the advantages offered by today's versatile phenolic materials. And from the application of Plenco's creative research and experience to your problem.

You can be sure that, with many years of supplying critical and competitive industry, Plenco has or can *custom-formulate* just the molding compound you need: ready-made or specially-made; general purpose or very special purpose. Our selections are extensive, our facilities ample, our representative always available for consultation. Call on us at any time.

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Serving the plastics industry in the manufacture of high grade phenolic molding compounds, industrial resins and coating resins

NEW BOOKS

ACRYLIC RESINS

Milton B. Horn, Reinhold Publishing Corp., 184 pp., $4.50

Acrylic Resins is par excellence in context and written with the dexterity of a novelist. One is hard pressed to find a justifiable criticism.

The theme of this book is guidance in application. This is carried out by introducing the reader to acrylic chemistry, the foundations of manufacturing and properties, thence on to the many products. These products include cast sheet, molding powders, emulsions, solution polymers and specialty applications of acrylics. Each topic is fully covered and surprisingly current in its treatment. A number of inaccuracies were noted, but these were on very minor points which had little importance on the overall subject matter.

This book should definitely become part of the library of everyone connected with plastics, especially since it represents one of the few texts on the important acrylic materials.

Alexander Jung
Rohm & Hass

PROPERTIES OF MATTER

F. C. Champion and N. Davy, Philosophical Library, New York, 1958, 334 pp., $10.00

The main characteristic of this third edition is the development of the atomic and molecular concepts in their relation to the various aspects of the behavior of matter. It is obvious that the most recent discoveries of our atomic age have modified and made more comprehensible facts which in themselves and also in relation to time were not as easily understood a few years back.

The authors, well aware of this, have given the reader, in a concise form, essential data which should be the basis of everyone's knowledge on this subject. Matter is described in connection with gravity, gravitation, elasticity, compressibility, seismic waves, capillarity, surface films, kinesis, osmosis, diffusion, viscosity and Planck's constant.

This book is a "must" to the curious reader, both for its philosophical and practical aspects.

Dr. Louis C. Barail
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PROGRESS IN DIELECTRICS, VOLUME 1

Edited by Dr. J. B. Birks and Dr. J. H. Schulman, John Wiley & Sons, Inc. 271 pp. (numerous tables and figures, 15 photographs), $11.00.

From the preface we learn, "The aim of this series (note: this is the first volume published) is to provide a common meeting-point for all interested in dielectrics, to co-ordinate our current knowledge of dielectric phenomena, materials, and techniques, and to review recent progress in different aspects of the subject." If volume 1 is representative of those to come, the editor will meet this avowed goal.

This volume covers dielectric breakdown in solid insulation, breakdown effects in crystals, dielectric liquids, gases and non-oxide ceramics, ferroelectricity of barium titanate single crystals, and concludes with electrophoretic deposition of insulating materials. Each is covered in from thirty to fifty-eight pages by eminently qualified authors.

The last chapter on electrophoretic deposition exemplifies the careful preparation that has gone into the volume. We were pleased to note the details on not only the theoretical but the practical phases of anophoresis and cataphoresis. Sometimes, of course, details that might be wished for were absent, but in such a compendium this must be expected.

One disappointment was the lack of data on epoxies, polyesters, and polyurethanes as dielectrics. It is hoped this will be covered in future volumes. Material on foams will also be required. On the other hand, many useful conclusions will be found. Again, a short-coming—no index. Perhaps this is now considered a needless member—an appendix. This writer happens to consider it vital.

For those interested in dielectrics, in spite of the shortcomings noted, this volume should be a needed and welcome addition. So much is happening in this field, no one can keep completely abreast more easily than thru a volume such as this one. If you wish to strengthen future volumes, certainly a letter to the editor will not be casually dismissed.

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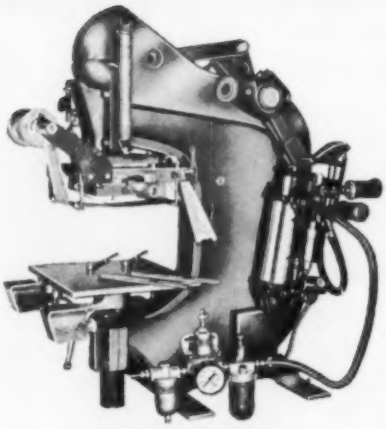

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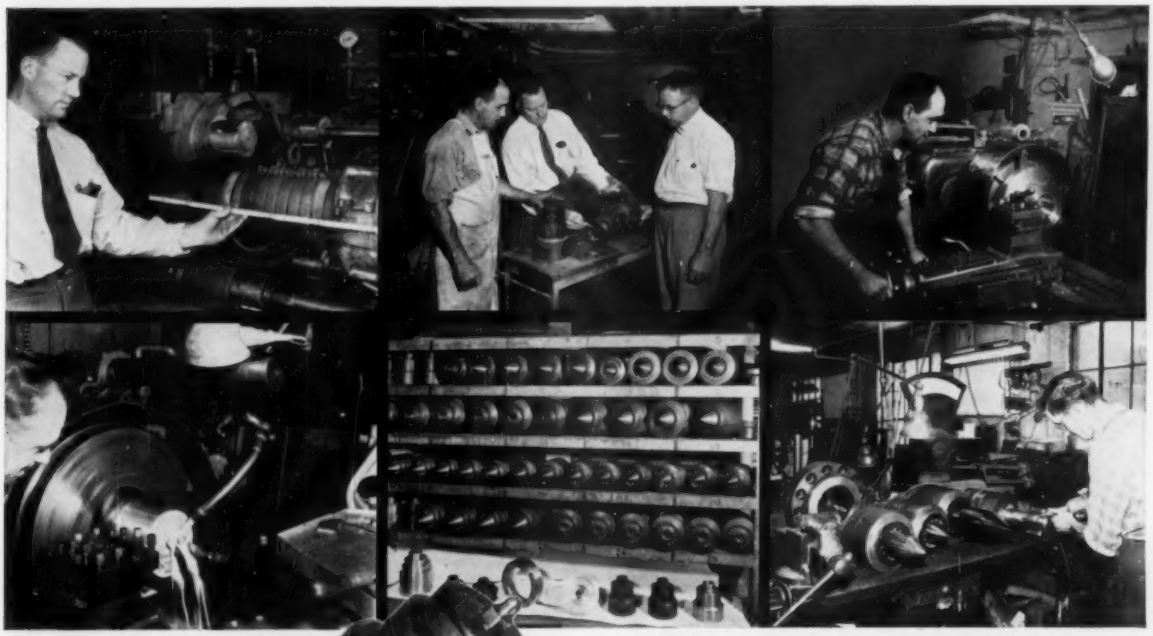

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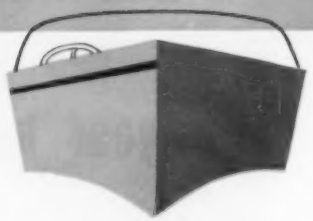

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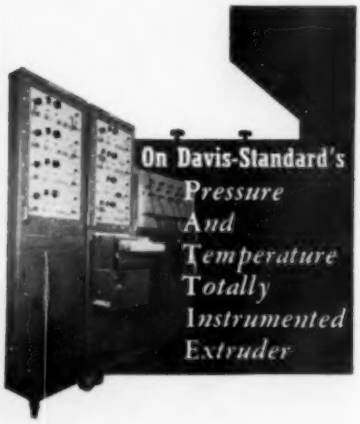

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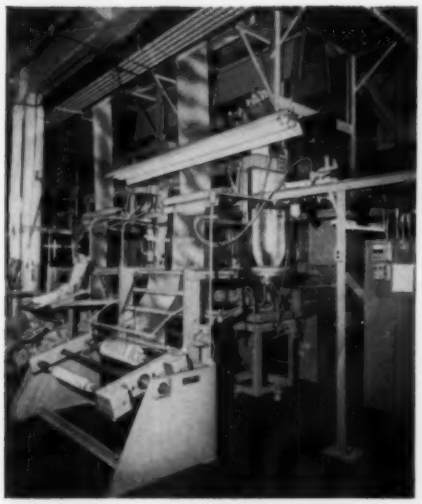

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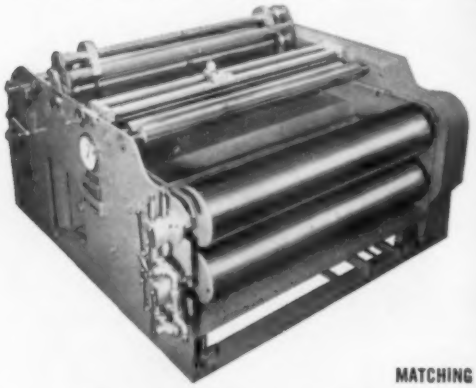

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1960 RETECS

September 8 and 9—New Horizons in Vinyls and Plastics in the Shoe Industry, Eastern New England Section, Statler-Hilton Hotel, Boston, Mass., Co-Chairman, Program, Robert Abeles, c/o Elfskin Corp., Main St., Cherry Valley, Worcester, Mass.

September 22—Plastics in Business Machines, Binghamton Section, Sheraton Inn, Binghamton, N. Y. Chairman; John E. Gwyn, c/o Consolidated Plastics, 498 Conklin Ave., Binghamton, N. Y.

October 5—Plastics vs. Corrosion, Golden Gate Section, Mark Hopkins Hotel, San Francisco, Calif. Chairman: J. W. Richardson, c/o Rohm & Haas Co., 600 California St., San Francisco 8, Calif.

November 7—Automation in Injection and Compression Molding, Ontario Section; location: King Edward Sheraton Hotel, Toronto. Chairman: J. M. Lees, c/o Canadian General Electric Co., 755 Division St., North Cobourg, Ontario, Canada.

November 18—Blow Molding, Newark Section, Essex House, Newark, N. J. Chairman: Robert Hoehn, Mack Molding Co., Ryerson Ave., Wayne, N. J.

1961 RETECS

April 25, Indianapolis, Ind., Central Indiana Section: **Plastics for Tooling.** Section President: Milton Brummer, 4241 Marrison Place, Indianapolis, Ind.

May 9, Detroit, Mich., Detroit Section: **Plastics in the Automotive Industry.** Section President: John D. Young, E. I. du Pont de Nemours & Co., Inc., 13000 West Seven Mile Rd., Detroit 35, Mich.

October, Niagara Falls, N. Y., Buffalo Section: **Foams.** Section President: William Dunmeyer, Carborundum Co., Buffalo Ave., Niagara Falls, N. Y.

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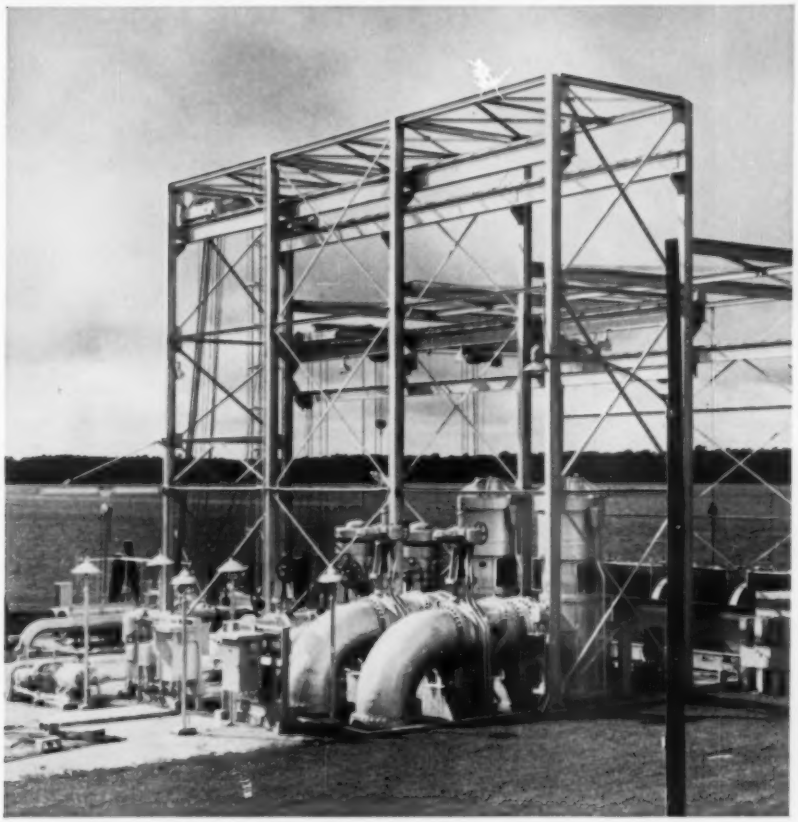

Florida Power & Light Company uses anode racks made of Geon vinyl pipe. Fabricated by F P & L plant personnel at this job. B.F.Goodrich Chemical Company supplies the rigid Geon vinyl. These photos show intake structure at Palatka plant on St. John River, one of many places anode racks of Geon are used.

FP&L fights underwater corrosion with anode racks of rigid GEON

Underwater steel structures corrode when they are attacked by galvanic currents. Florida Power & Light engineers solve the problem two ways. They reduce effect of galvanic currents with an opposing voltage and they suspend anodes of graphite to bear the brunt of any continuing flow. These anodes rest in frames made of rigid Geon pipe.

Vertical side frames are 2″ Geon pipe and trays are open sections of 5″ pipe. The only effect on the racks of Geon is the marine growth shown in the photo at upper right. This growth is easily washed off, as photo at lower right shows.

Here's another example of the way Geon vinyl can solve corrosion problems for utilities. As pipe, as conduit, or as coatings, you'll find Geon vinyl is often the answer to your corrosion problems. For more information, write Dept. GM-5, B. F. Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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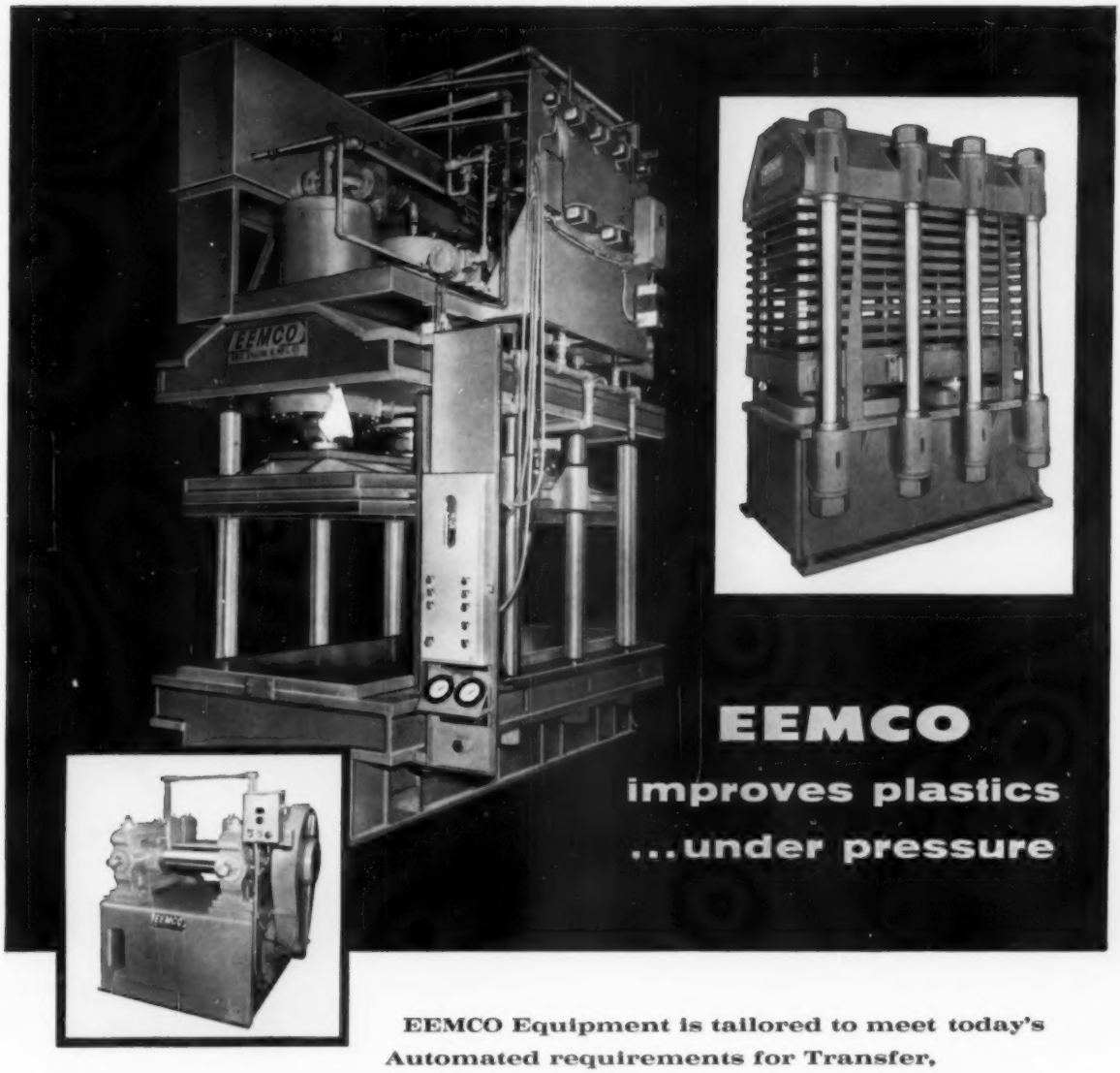

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